Chapter 4

About ORGANIZATION, where research was carried out

4.1 Perspectives of Bulk Ore Industry - Ore Logistics Chain

Goa is a small state on the Western Coast of India stretched over an area of 3702 sq. km. Gifted with nature’s bounty & a checkered historical background, Goa is a very attractive place. The Western side of Goa is bordered by the Arabian Sea with approximately 105 km coastline and Eastern flank bordered by the hilly stretches neighboring the states of Maharashtra and Karnataka. A tourist map of Goa is referred at appendix 1.

Goa was ruled by the Portuguese Government for over 450 years and was liberated from Portuguese Rule in 1961 but remained a Union Territory till May, 1987 when Goa was declared the 25th state of India.

Mining in Goa has its deep-rooted history with first mining concession granted by Portuguese govt. in 1929. The first export of iron ore to Europe dates back to 1947, post which a no. of concessions were granted by same govt. and later converted by Govt. of India through a decree. The industry created employment close to a lakh people (directly and indirectly) and nearly 25% of the Population of Goa is dependent on Mining or Mining related works.

While Goa is blessed with minerals such as Iron, Manganese, Bauxite and perhaps limestone and other minor minerals, it is the Iron Ores which is most prominent. Iron ore deposits of Goa essentially consist of oxides of iron ore hematite and partly of magnetite. The ore being of low grade, with high Alumina & Silica and therefore needs to be processed by various methods such as scrubbing, wet screening, gravity separation etc. in order to render them marketable. Goa also has the credit of having pioneered the exports of iron ore from India. Goan ore exports amounts to almost 70% of India's Iron Ore, clocking 43.27 million tons per annum in 2011. Ore is exported in the form of lumps and fines primarily to China followed by Europe, Japan, South Korea and
other Asian countries. Pallets are still a very small fraction of total exports. Furthermore the industry was the highest contributor to the revenue of the State of Goa, as over Rs.1250Crores in taxes were paid by the mining industry to the State apart from approximately Rs.6500Crores to the Central Government in the year 2011-12. Mining Industry is also responsible for bringing in foreign exchange as is evident from the fact that the industry earned foreign exchange to the tune of Rs.37000Crores during the period 2009-2012. (Source: Goa Mining Ore Exporters’ Association report, 2013).

In other words, the Goan Iron Ore industry is wholly dependent on exports. Goa's in-situ iron ore is comparatively of low grades. Most of the ore range between 54% - 61% Fe content. Nowhere else such ores are considered to be marketable. In fact, in other parts of the country such type of ore is treated as rejects by domestic steel producers. Goan ores, therefore, have to go through an elaborate process of beneficiation / concentration to render them usable by domestic steel mills. Chinese steel mills, in particular have found ways to blend such low grade ores with high grades of ore available from other sources (e.g. Australia, Brazil, etc.) and have made Goan ore their preferred choice while preparing recipe for their blast furnaces’ feed. Stringent demands by select customers have resulted in the Goan Mining Industry to consistently improve on its mining methods, always aiming to better its past performance.

![Figure 2- A typical open cast iron ore mining pit of Goa with mining benches](image)
4.2 About Ore Supply Chain

Any mining operation would begin first with the prospecting and exploration of virgin lands. Bore wells are dug and the lithology of the samples is studied. Geologists then interpret the structure of the ore body. Various software packages have been used in the last few years in the preliminary mining activities, such as reserve calculations, plotting, etc. Open cast mining operations start after systematic planning is done to mine the ore reserve. The top soil is removed and stacked separately as it is the most useful for revitalizing the green cover. The overburden, which is stacked separately, is covered with the top soil and later afforested to restore natural green cover and thus minimize environment impact due to mining.

With half the world's iron ore requirements met by imports predominantly sea-borne, not only does the shipment of huge quantities of iron ore worldwide pose unique handling problems to both producers and consumers, but ocean freight, together with other shipping and cargo handling costs, make up a large part of the cost of the cargo delivered to steel makers. However Goan ore industry has been blessed uniquely in this respects as explained further.

The coastal location of the State, the proximity to a natural seaport with modern amenities coupled with gifted navigable Waterways, close to mining areas is perhaps one of the most significant advantages to Goan mining industry. This offers a combination of road and inland waterways modes for the ore to reach seaport, thus providing the most economic and efficient logistics modes. This is the prime reason why Goan ores, despite having an inferior Iron Content and no domestic market, are mined, processed and transported efficiently for exports. Goa thereby historically makes its mark in the International Iron ore markets.

Inland Waterways of Goa

Goa is gifted with a large no. rivers and estuaries but only Mandovi and Zuari rivers are navigable for cargo carriage. Whilst Mandovi River is the lifeline of North Goa district, Zuari River is for South Goa. The navigable safe draft in Mandovi river is maintained about 3.2 mtr, while Zuari is about 2.5-2.8 mtr, thus limiting the maximum cargo
capacity of barges while navigating in these rivers. With the onset of every monsoon, the Captain of Ports dept. (COP), a state appointed authority, issues necessary guidelines for closure of Aguada sand bar, thus allowing only restricted Mandovi river navigation through Cumharjua canal, a rivulet offering low-draft passage to barges willing to operate in Mandovi river for cargo handling in Mormugao port. The safe draft in the rivers is prescribed and maintained (by de-silting through dredgers) by COP, the regulating authority for all vessels operating in these rivers.

Shipping Facilities in Goa

Goa has 2 ports: Mormugao Port, a natural harbour offering mechanized ore handling berth and Panaji port, a minor port, offering only mid-sea loading. It is also a distinct feature that Mormugao port offers access to cargo only through barges and no road access is currently available for Goan ore, while the ore from neighboring state like Karnataka can get access through rail route.

The mechanized ore handling plant at Berth No.9 in Mormugao Port has limited capacity (about 11-12 million tons) and hence the rest bulk cargo handling is done through Trans-shippers harboured within the Port limits of Mormugao & Panaji Port as well as by manual loading in Mid-stream or in Mooring Dolphins installed by Mormugao port in last few years. Berth No.9 is exclusively allocated for handling Iron Ore. At present the limited draft at Berth No.9 permits the loading of vessels only up to 80,000 tons and therefore any Cape size vessel has to be up topped (beyond 80,000 tons to 200,000 tons or more depending upon its capacity) by trans-shippers, which are owned and maintained by the exporters. The trans-shippers thus play a complementary role in the port's operations and help raise Mormugao port to international standards.

The Mormugao Port offers a wide range of standard facilities for pilotage, towage, lighterage, bunkering, loading, unloading, transit sheds, warehouses, freighting, medical aid and supplies etc. Repair and service facilities are available at Goa Shipyard, Government of India Undertaking, and at other specialized private firms.

Panaji Port, a minor port under the control of Captain of Ports, a state authority, operates only in fair weather i.e. from October to May every year as the sea becomes
rough (unsuitable for mid-stream loading / discharge) in monsoon. Loading at this port is
done with the help of trans-shippers or manually with ship’s own gear in mid-stream.
The congestion at Mormugao Port is thereby reduced with the operation of Panaji Port.
The loading capacity in this port is therefore governed by the capacity of trans-shippers
operating there or manually to about 15,000 tons a day per vessel in fair weather.

4.3 Ore Logistics Chain for Export

Ore Logistics Chain consists of movement of ore (of exportable quality) by road from
mines or processing plants to the nearest storage locations, normally closest to riverine
jetty, followed by internal movement within the riverine jetty to load barges and finally to
mother ship (destined for customer) via the inland waterways (through navigable river
waters) and sea.

Transportation of the mineral in Goa is carried out through road and inland
waterways, a uniquely gifted natural combination of modes providing cost economy and
efficiency. Let us discuss each mode in detail from the perspective of supply chain
under study for the purpose of automation, while touching chord with inherent issues
and concerns:

A). Road Transportation

i). Long haul Road Transportation:

Ore produced and processed at mines/plants is transported by tipper trucks hired
from the local villagers, using private and public roads to the river side jetties. Such
arrangement by various mining companies across the state is a common feature to
ensure Public participation in business activity and thus a larger mass of the society is
involved to share the prospects. Hence it can be well termed as unique model of
cooperation between industry and local populace. This is the common model of
corporate social responsibility for all mining companies and in this manner, the
companies also get due support from nearby communities in various ways.

To check on pilferage and overloading, road weighbridges are installed at exit point of
mine and at the receiving point. The ore carrying trucks are covered with tarpaulin
before exiting mines, as an anti-pollution measure to protect against dust pollution en-route. Likewise many mines have provided for ‘wheel wash system’. In this system, the trucks are allowed to pass through a trough of water and then climb a ramp where special water jets sprinkle water on the tyres, cleaning the same. Some of the companies have also installed rumbler system (dry wheel wash system).

Water tankers, mechanical road sweeper, manual sweeping are used to keep the transport route free from dust to the maximum possible extent.

The kind of run-off systems shown in pictures (figure 3 below) have become more important and relevant after the recent imposition of restricted transport timings (~8-10 hours as against earlier almost 24 hours) by local administration.

ii). Short Haul Road Transportation / Handling in Jetty

As the name suggests, short haul is movement of products over a short distance, usually within same compound or mine or jetty. For this research, it refers to loading of tipper trucks within a stockyard in jetty and move the truck to the jetty platform for discharging the contents into barge hold via the weighbridge.

Other examples of short hauls are movement of crude ore waste or overburden from mine pit to the dump yard or crude ore trucks moving from mining pit to product storage yard.

The difference between long-haul and short-haul is reflected in the weighment process as usually short-haul trucks are weighed only once either at source or at destination. This is because the trucks are moving within the same perimeter of compound / mines / jetty and there is no way for the cargo / truck to escape. Hence the process becomes much simpler. Also usually such short-haul movements are contracted out to just one big contractor, who can mobilize large truck fleet and thus it does not become necessary for the miner / exporter to keep or share truck-tipper wise performance data. This further makes the solution simpler wherein exporter does not have to identify each truck for saving data in terms of weight and time etc.
Thus we find that short-hauls trips are easier comparatively to capture and this is explained separately under the head ‘Auto-Id’.

B). Transportation through Inland Waterways:

Ore received at river-loading jetties is thereafter transported by way of barges to the ports of discharge for loading into mother vessels (ocean-going large capacity vessels), nominated by buyers or by mining companies on behalf of buyers. Barges are small sized vessels built with or without self-propelled capacity as certified / monitored by Captain of Ports department. The barges transport cargo ore from jetties to ports i.e. from river to the sea, where mother vessels wait, for loading either at berth with shore mechanized handling facilities or in mid-sea with the use of trans-shippers. Due to limited draft and cargo handling capacity at the port berths, many local mining companies have invested in trans-shippers (transfer vessels) to discharge ore cargo from barges to vessel. Practically almost all barges in Goa are now self-propelled with cargo carrying capacity in the range of 1300-2500 metric tons. The Inland Waterways of Goa have the coveted distinction of lowest accidents in the country over the past decades, thanks to the competent barge crew certified by Captain of Ports department, manning and operating these barges. Each barge is manned by a crew complement of 9 trained members for a fortnight shift and is replaced by another crew complement for the next shift.

C) Mid-sea Loading through Trans-shippers

Since the ore handling capacity of mechanized berth and its draft available at Mormugao Port is limited, many exporters have invested in transfer vessel to up-top balance quantity, thereby enabling even larger cape size vessels to call on the Port. Currently a no. of trans-shippers are operating within the Goan coast, such as: (a) Maratha Deep; (b) Priyamvada; (c) Orissa; (d) Satixa; (e) Goan Pride; (f) Royal Sesa; (g) Vishal Hira, etc.
Due to these trans-shippers, vessels of more than 200,000 DWT can be easily loaded at an average output of around 20,000 ~ 25,000 tons/day per trans-shipper. On an average, around 35 ~ 40% of the total exports from Goa i.e.20 mtpa is loaded by trans-shippers. The Largest Iron Ore Vessel that has called in Goan Ports is M.V. Alster Cove, this was 300,000 DWT.

B). Key Differences of Goan Ore Supply Chain Logistics and measures of performance evaluation

In the previous chapter on Industry perspectives, we have seen how the Goan landscape is unique in many ways and offers unique opportunities of leveraging river and sea logistics to replace a large amount of road journeys being performed in most states in India, being hinterland or due to absence of navigable waterways for commercial exploitation.

Govt. of India has recognized the importance and contribution of inland waterways in boosting the trade and commerce by its salient advantages of cost economy and efficiency, that’s why Inland Waterways Authority of India have been formed to conceptualize and develop more and more such projects (also announced as IH 1 or IH 2 just like NH 1 or NH 2, the most recent one is named as IH 1- Haldia to Farakka across Ganges). However it is hoped that state government and central government would hold talks to iron out perceived and real differences with regard to declaring these Goan waterways as National Waterways for harnessing full potential of water navigation opportunities for realizing dream of one connect India as far as its rivers are concerned, for larger benefit of society.

4.4 About Case Company where this research project work is undertaken

Having studied the inherent characteristics and detailed structure of Iron Ore industry of Goa, the next task for me was to shortlist the best two member organizations of Goa Mineral Ore Exporters Association, where it would be feasible to conduct my research project. Obviously my selection alone was not enough, as the other end (i.e. organization) also must agree to allow me to access their processes and past data, so as to set baselines of relevant KPIs to study the impact post-automation. Hence it was
equally important that this organization must be made aware of likely challenges, likely supply chain disruptions which sometimes may erupt due to unintended misfires in planning, and hence it must have right kind of risk-taking appetite as well. Besides this, its managers must also have appetite for absorbing state-of-art technology, to see it working live by rolling it out to other locations once it is demonstrated successful.

While the above demands may look a bit theoretical to appear only in a fantasy land and not in real business world, but I was really lucky to have not only spotted such an organization, but also having received their in-principal verbal agreement to partner with me for providing necessary financial and organizational support for the pilot site implementation.

The figure 4 below shows simplified organization chart i.e. Top Management Structure of case company

![Top Management Structure of Case Company](image)

4: Organization structure of case company
The only condition they laid was that of anonymity with regard to their identity but allowing me to use the data after codifying key parameters (publicly known domain set such as location of mines / plant / jetty / name of mother vessels etc. etc.), while all software developed for the purpose would be retained by them for their future use and should not be deployed by development agency without their permission. Consequently scholar is bound morally in not disclosing name of the company and wherever possible, has used code-worded locations in order to respect the gentlemanly agreement made, however ensuring that such code-wording does not result in suppressing any critical information as may be necessary to comprehend the results or impacts, even by a lay man.

The only reason that I can hazard a guess now, about such a demand (of non-disclosure of identity) of this organization could be their status / reputation of industry leadership, which they did not want to jeopardize by having to attach their name with an ordinary common man scholar like me, in case such an effort would have failed. And in case I succeeded, they would have anyway been victorious as the benefit of successful automation implementation would bring innumerable tangible and intangible benefits to their organization. But whatever that be, I must salute their spirits and feel great to have found such partner organization so easily, almost in 2nd attempt itself.

4.5 Product Profile of the Case Company:

As explained above, the case company is a member of the Goa Mineral Ore Exporters Association and is one of the leading companies in this industry, contributing to a substantial share of Goan export volumes of iron ore. It has multiple leases of iron ore mines, spread across Goa. It has a no. of riverine jetties owned by them, on Mandovi River banks in North Goa and at least one jetty on the banks of Zuari River in South Goa. Almost all the mineral production is of medium grade i.e. 52-58% Fe2O3 from open-cast mines through the use of excavators and dumpers, whereas best quality ore can be having Fe2O3 as high as +63%. The excavated ore, called crude ore would invariably require beneficiation through wet and/or dry plants in Goa, whereas in rest of the parts of India and world, crude ore in itself may be dispatched directly as finished goods, if other impurities like Silica, Alumina and phosphorus etc., are in acceptable
limits, depending upon the process and geological structure and properties of natural ore. The wet plants use water to wash away impurities including some clay / silica etc. to get enriched ore with higher Fe₂O₃ contents (may or may not be of lower silica depending upon the process and geological structure and properties of natural ore used). The remaining impurities get accumulated in the form of wash rejects, which are then pumped into tailing ponds. The tailings would get accumulated in a settling pond and would be retrieved after it has become considerably dry and would be sold in market depending upon quality and demand, or else would be dumped in mines for afforestation gradually (not allowed to be left as it is, to avoid degradation of environment).

The processed ore / natural ore would then be stacked in large heaps on ground in the form of heaps or piles and would be tested by laboratory to confirm its quality before dispatching to customer. This finished product can be either fines (normally 0-10mm) or calibrated lumps (screened to max size), with specified maximum and minimum range of physical size (10-50 mm), as is specified by buyer (steel Mill customer). In case of lumps, one as to take care that they are not broken or get crushed to smaller size, else customer may not accept the quality on receipt.
Figure 5 below illustrates supply chain process flow of ore cargo exports.

Figure 5: Illustrated diagram of supply chain Process flow.

The key aspect of planning, organizing, execution and control is handled by 3-tier organization structure of Logistics department as explained in figure 6 below. In order to get a first-hand feel and experience of Goan supply chain complexities, it was necessary to undertake a walk-through mines’ logistics and understand the key salient characteristics of each of the road and barge transportation. Later even the key vendors of the project and key stakeholders were also given a walk-through of actual supply chain of the company with the help of company’s Logistics personnel to help them understand better in field.
Figure 6: Organogram of Logistics department of case company

Thanks to various coordinators appointed by the company, who took us through the entire process in field and on drawing boards, which helped me and the system integrator agency not only in appreciating the difficulties faced by them but also enabling us to explore the vast technological options deeper. This made us meet a no. of field managers controlling the operations as well as a few stakeholders like transporters and barge owners, sharing their insights, some not so formal but key to understanding the human dynamics of collaborative supply chains, rarely explained in any book or article.

**S & OP Process:**

Before explaining the individual mode of transportation, I would like to explain key features of S & OP process, which the case company has institutionalized in order to ensure proper coordination between various stakeholders of actual export of cargo.

The S & OP section is directly reporting to COO-Mining and is manned by a General Manager and a Manager assisting him. This section is responsible for monthly planning of ore dispatches, basis pending orders and priority decided by Marketing functional Head depending upon customer’s requirements (timing as well as CFR or FOB terms of supply), while balancing the available capacity of loading assets i.e. trans-shippers and barges, coupled with maximum possible road evacuation feasible. The problem becomes complex when multiple loading assets and grades compete against each other, while maintaining transparency with customer as he may complain that his ship (if under FOB terms of supply) may undergo demurrage (i.e. attracting penal rates of freight charges for detention beyond agreed period). This is easier said than done in a
dynamic world, where there would be no. of factors would change and thus forcing the company management to maintain balance in terms of volume and cost.

There have been a no. of times, when conflicting interests of individual functional optimization (cost or capacity or any other factor) start hindering the overall objective set by management for that month, in the form of volume target and Sales realization target. Hence under such conflicts, the role of such a neutral but competent S & OP Manager becomes evident, so that the resolution proposed is the most optimal solution for the company as a whole, under prevailing circumstances (even though it may not be optimal for any particular function/section).

While the company has tried to address these concerns by trying to institutionalize S& OP processes, however it has not been able to correspondingly resolve some of the fundamental challenges in its Logistics chain such as lack of transparency and availability of same information to all chain partners or even its own decision-makers due to working in a functional silo manner all these years. There have been no. of incidences wherein one section of logistics function almost blind-shielded availability of key information to other sections, thus leaving them lurking large in the dark for better planning and utilization of its assets. Whilst S & OP may be attempting to break through such shield, but sometimes it was not the worth of time and effort spent.

4.6 Process Flow and Components of Company’s Supply Chain

Let us now briefly discuss different legs of transportation involved in export of ore cargo:

4.6.1 Road Transportation of Cargo: Long-Haul Movement

The movement plan (monthly, weekly and daily) is prepared and monitored for all Mines / processing locations including transit locations, so as to stock pile the cargo of required quality at Jetty location. The truck fleet is dedicated for a particular route, but entirely outsourced under different engagement models like permanently hired (usually directly with individual truck owners of nearby villages en-route) or need-based hiring through transporters. The permanent-hired trucks were painted with allotted serial numbers (not number plates) on the truck body, to facilitate ease in recording and
identifying the particular truck by all stakeholders, like security guards at Inward and Outward gates, loading machine and weighbridge operators etc.

Figure 7: Logistics Process Map of ore export for a typical Goan exporter

The mobilization of fleet and traffic control at all locations (inside mines and outside on the road to jetty) was the key to daily rigor in terms of ability to transport the cargo for export. Everyday morning the truck drivers would start queuing up at the Inward gate, waiting for loading to start at designated stack-points in the mines. Once loaded, the trucks would report at the designated weighbridges (for a particular route / destination) for gross weighment of cargo. Here I would like to draw special attention to the following process deficiency:
The trucks would not be weighed for their tare weighment every day, rather all source locations were following different cycles / frequency, e.g. fortnightly at sources of lesser daily loading and monthly for higher daily loading sites. Hence the net weight being arrived at the weighbridges was after subtracting such old standard weight. This might creep in error and at higher daily volume evacuation scenario, such differences could be substantial, without even getting detected. Since the local district authorities had capped maximum weight or capacity for such truck tippers, it was many times necessary to re-send the truck from weighbridge to loading stack for removal / addition of more cargo to reach desired weight-range.

<table>
<thead>
<tr>
<th>Process Point</th>
<th>Description</th>
<th>Name</th>
</tr>
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<tbody>
<tr>
<td>Stack Point</td>
<td>Different materials are stacked into different locations at the site. The truck gets loaded with the material using a Wheel Loader at this point. The loaded weight of the truck is weighed at this point. The amount of weight is adjusted to weigh 10 tons net by adding or removing the material from the truck. The truck after collecting his slips and permits leaves to destination for unloading. The loaded weight of the truck is measured at this point. The truck, after collecting a sealed slip comes to this place for unloading the material.</td>
<td>Loading Point</td>
</tr>
<tr>
<td>Destination Point</td>
<td>Security Entry Gate into the Mines</td>
<td>Intermediat</td>
</tr>
<tr>
<td>Unloading Point</td>
<td>After unloading the material the truck reaches this point for getting its tare weight measured.</td>
<td>Tare Weight Point</td>
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Figure 8: As-Is Road Logistics Process Flow Chart Visual

There used to be always chaos near the weighbridge despite deputing security guards for maintaining discipline, as the truck drivers would get down at the weighbridge for handing over loading advice (giving truck no and grade / stack number) and collecting the Delivery Advice (DA) after the weighbridge operator keys in all necessary details in the weighbridge computer and give command for printing DA. All these activities were taking huge time, almost avg. 2-3 minutes per truck and hence the drivers used to wait in queue for as much as 30-60 min. depending upon occurring of various bottlenecks. Above figure illustrates As-Is process flow chart with process point legends.

After collecting the DA from weighbridge, the drivers would queue up at the designated space for covering tarpaulins on the cargo truck, with the help of labor gang available there. After tarpaulin covering in place, the drivers would leave the mines trough the Outward gate, while handing over one designated copy of DA to the security, who would
scrutinize the needful details to confirm authenticity of cargo leaving. The trucks cover the journey to the destination, through specified route, after witnessing multiple hold-ups at various junction points en-route through the congested narrow roads, not so safe for general public all the time in terms of crossing the road for shopping in various markets en-route or for or other needs.

After varying time-intervals, the trucks report at destination jetty Inward gate and await in queue for their entry to jetty weighbridge for gross weighment. The security guard posted for each queue maintains a manual hand-written register for truck number entry / time. The truck then gets the gross weight slip by handing over the source DA to the operator, who in turn keys in the trip no. / Truck number in the system to re-collect the previously entered data from source location (s. t. internet network availability with the source location, else just enters the full details of DA in the system). The truck would now leave for unloading stock-yard at jetty and would get the weighment slip stamped by unloading supervisors, to be submitted back to the source location as proof of delivery. The trucks would then leave jetty location after security inspection, without undergoing tare weighment, which was perceived by me as a serious internal control gap, had there been connivance between security and truck drivers.

With this, the road transportation process of the cargo is completed, leaving the analysis part of the data and information to determine process efficiency and effectiveness.

The biggest challenge now to be faced was in terms of reconciliation of trucks that reached destination, as it was completely manual job. This was being attempted by a large team of 2-4 people at all source and destination locations to detect missing trips or short delivered quantity by coordinating the transactions with destination teams. Scholar had spent a huge amount of time in working with different source-destination teams in order to first understand the quantum of job involved and later trying to help them by devising some data segregation criterion to help them improve focus in detecting the short-delivering defaulting truckers, of course the missing trip detection was still a herculean task. The no. of daily trips were quite large to be scanned manually next day for finding the non-matching truck numbers between source and destination weighbridge records, as wrong punching of truck nos. was most common problem. This
required frequent / multiple checking and a lot of guess work, which resulted in a lot of pile-up of pending work as well as creating scope of mistrust as one would be chasing the transporters / drivers for submitting stamped delivery receipt document.

**Tipper Trucks**

![Tipper Trucks](image-url)

Figure 9: Typical Tipper trucks engaged in export road transportation

However frankly speaking, I found lack of business hygiene and absence of internal controls, as the whole reconciliation process was left to be driven by junior most team of executives.

It was obvious that the road transportation system required further tightening of controls during movement of cargo whether for long hauls or for short-hauls, because most of the mines were operating under porous boundary (meaning no physical boundary wall erected with neighboring mines, thus leaving scope for crisscross movement across neighboring mines).

In case of Karnataka mines, the cargo loading process at the source was same except for the special inter-state documentation done at the weighbridges as prescribed by state government (mining as well as forest dept.). The trucks from Karnataka mines
would be received at the nearest jetty locations in Goa or at the steel plant inward gate, following same process as at the destination jetty explained above.

We summarize major Challenges in Road Transportation of Goa, internal and external as:

- Road congestion due to poor infrastructure of roads / bridges. Infrastructure available is not designed for higher capacity trucks.
- Local villages’ opposition to increased traffic density due to related nuisance like dust, noise, accidents etc.
- Frequent transportation holidays due to local festivals along the transportation routes and long monsoon during June-Sept, thus restricting available days in a year.
- Restriction in transport timings by state Government.
- Internal discipline and competitive volume pressures resulting in lack of cooperation amongst industry players.

4.6.2 Road Transportation of Cargo: Short Haul Movement

As explained earlier, short haul is movement of products over a short distance, usually within same premises boundary (in mine or jetty). Since our study is in supply chain arena, it refers to loading of tipper trucks within a stockyard in jetty and movement of the truck to jetty platform via the weighbridge, for discharging the contents into barge hold.

The short-haul movements in jetties of our case company were being contracted out to just one contractor in each jetty and thus it does not become necessary for the miner / exporter to share truck-wise performance data. The short-haul trucks are weighed only once either at source or at destination as both source and destination are in the same premises and there is no way for the cargo / truck to escape. Hence the weighment related controls became much simpler with just one weighment, either at loading or unloading end. Further there was no need to identify each truck for saving weighment data as it was found that all the trucks were identical with almost similar tare weight, baring a small negligible difference. Thus we relied upon ‘Auto-Id’ solution for short-
hauls trips to capture gross weights for each trip to make the process faster without loss of accuracy. In short, we can say that there was not much scope for any business process reengineering (BPR) as was for long haul.

A word of caution here that such Auto-Id solution was feasible for within jetty movement, but may not be possible to replicate for other internal movements like within mines movement for waste and ore transportation.

**4.6.3 River Transport of Cargo**

The Goan mineral ore industry and the company makes full use of Inland Waterways in the State of Goa for transportation of all its ore from riverine Jetties to the Port (berth or mid-sea loading). Most of the exporters either own or hire jetty for this purpose with a view to approach nearest jetty location to reduce the road transport leg as minimum as possible. One of the jetties owned by the company is also equipped with shore cranes and conveyor system to discharge cargo (incoming coal / ore) for its captive steel plant. All jetties usually have space for stacking / storage of cargo as well as one or multiple barge loading platforms. The road trucks bringing cargo from mines / processing plants unload the cargo material in the jetty stacking yard (cargo storage space), which then gets mechanically handled by front-end loaders or excavators for sun-drying for a few days till its moisture contents are reduced to the desirable range.

The mining companies either own or hire barges to carry their cargo from jetty to port berth or mid-sea locations, where mother vessels are parked / anchored. The case company also owns and maintains a fleet of barges, manned by competent licensed crew, complying with safety standards / practices prescribed by Captain of Ports (COP) department, under the aegis of State Government. In order to maintain these barges, company has also set up a full-fledged Ship Building Division, responsible for annual repairs and maintenance of the barges, to keep them safe for plying under relevant provisions of water carriage act. A typical size / capacity of barge operating in Goan waters presently is about 1800-2000 DWT, however it can vary between 1000 DWT to 2800 DWT size depending upon size and max draft allowed.
The barge would report at the jetty on arrival, and would await in nearby parking bay for their loading turn in sequence, while de-ballasting the tanks. Once called by the Jetty team, the barge driver would place the barge along the jetty such that its cargo-hold is placed just below the loading platform, while throwing the lines for mooring the barge along the fixed buoys, installed on the jetty for the purpose. The jetty in-charge would now instruct his truck-tipper fleet to load and carry the required quality of cargo from stockyard. The loaded truck would report at the en-route weighbridge for gross weighment and net weight would be arrived through use of standard tare weight, being determined at periodic intervals. The loaded tipper-truck would continue its journey to the barge loading platform, reversing just near to it, so that its cargo trolley is facing the river end of platform, for unloading the cargo contents into the barge hold, awaiting just below the platform.

A series of tipper-trucks would continue making trips in similar manner, till the loadable qty. is achieved for that barge, as determined by its Cargo-Safety mark on the body, called load line (touching water level). Such a mark is inspected and certified by COP office during annual certification of barge, depending upon a no. of factors like cargo
hold volume, safe waterline above the board, sea water density, etc. Usually it is a standard practice to shift the barge a little (a few meters) to make at least 3-4 heaps of cargo in the barge hold for maintaining the barge on even keel for safety. The barge master is expected to de-ballast further as may be necessary during the cargo loading.

Once the loading is completed, the barge would take the necessary Boat Note duly signed by master and jetty in-charge, containing details of weight, cargo grade loaded, source jetty and intended destination i.e. port berth / trans-shipper / mother vessel. The Boat Note would again be signed by master of the trans-shipper or mother vessel, or by company’s berth supervisor at the port, as acknowledgement of full contents of cargo as mentioned, to serve as proof of delivery.

The key challenges faced in the river segment are growing dissatisfaction among its crew for having to work under pressure all the time in midst of sea when the cargo unloading is temporarily halted due to innumerable reasons such as TV breakdown or rejection of cargo due to TML (high moisture contents termed as Total Moisture Limit), bad weather etc. Besides these, there was a growing discontent in 3rd party barge owners over the shrinking margins in barge freight, due to excess capacity created in prior years and now that Karnataka ore was not available as well as maximum ore export from Goa was also being capped due to regulatory actions.
4.6.4 Sea Transport of Cargo

Operation of sea loading forms the last leg of our supply chain. All cargo loaded from jetties find its way to the mother vessel (hired by company or by Customer). Loading of mother vessel is done either at the Port berth or in mid-sea by using Trans-shipper vessels (TV) or by own grabs / cranes of mother vessel. A TV is a full scale PANAMAX or CAPE vessel or a Pontoon equipped with cranes and a telescopic ship loader with associated conveyors. The company owns and operates a fleet of Trans-shippers on dedicated or on shared basis and sometimes even hires a trans-shipper for a particular mother vessel.
All these assets (TV's) put together offer a substantial loading capacity, thus providing clean efficient loading arrangement to supplement the Port berth capacity. Over the years the company has trained and nurtured a team of Engineers with specialized skills to take care of operations and maintenance of these TV’s round-the-clock. In order to support such continuous mid-sea operation, the company also operates a launch service for the transportation of crew / material. It hires the pilot and tug service from port trust on case to case basis to help in placing and anchoring the TV along the mother vessel with mooring lines from mother vessel.

These trans-shipper vessels are the lifeline and unique feature of Goa sea port as these offer a lot of flexibility besides augmenting the limited port berth capacity available at Mormugao Port Trust’s dedicated iron ore berth.

**CAPE SIZE TRANS-SHIPPER**
4.7 Performance (KPIs) measurement of Ore Logistics Chain:

Having known the Logistics process flows in detail as above, it was time now to understand the various performance measures of the supply chain for this company. We now discuss these performance KPIs (Key Performance Indices) for each transport segment and measurement of KPIs to get a macro view of whether a particular supply chain is working to the satisfaction of its stakeholders and benchmark it.

For Road Segment:

- Transaction Time for weighment at the weighbridge and handing over documents.

- Turn-Around Time (TAT) for trucks – Internal TAT at source or jetty, Trip time irrelevant now as the individual exporter cannot influence much due to external challenges.
• Missing Trips – No. & ageing of missing trucks to take recovery action from truckers.

• Handling / Transit loss or Short Delivered Qty. at destination Jetty.

All above performance measures would be compared with pre and post-RFID implementation to know the impact of implementation of automation on the outward road supply chain and business performance thereof.

For River Segment

• Turn-Around Time (TAT) or no. of trips during the study period, of barges for different jetties – between source jetty to destination port.

• Handling or Transit Loss as computed for each mother vessel by reconciliation of cargo weight as ascertained by its draft survey and the total weight of all barge trips done for that mother vessel.

For Sea Segment

This segment, being the last leg of export supply chain, gets naturally debottlenecked from operations' automation point of view, as its feed (input) is through barges, which if gets to do more trips due to reduction in TAT, would invariably mean they would have to be discharged faster by trans-shippers or self-grabs of mother vessel (the optimization of port berth's barge discharging cranes, although taken up during this research project with concerned Mormugaon Port Trust (MoPT) authorities, but could not be influenced much, having its own echo-system to respond to. Hence it is implied that if the barge turn-around time gets improved due to automation of supply chain, it is implied that corresponding part of sea-loading has also improved as it is almost same as barge discharge.

Finally we conclude that performance improvement in supply chain as would be demonstrated through change in above parameters, is not possible unless coordination amongst various stakeholders is ensured by bringing in better visibility of critical information and events, by harnessing information communication technology. It would
be important to erase out old belief system of all stakeholders wherein they have been holding such key information to their chests, and provoke them now to use all other key information for pro-active action in the events of supply chain.

4.8 As-Is and To-Be Supply Chain Process Flow for road segment

‘As Is’ process-mapping exercise for all logistics routes across both segments of road and river-cum-sea were referred again and again to match with key demands of each technology options. The road segment consisted of Long-haul truck trips for movement from the mines to the nearest jetty as well as Short-haul trips for movement within jetty. The short-haul trucks were not identified at WB, but were just auto-weighed in sequence of trips performed.

Every time a truck leaves a source location, the truck driver has to carry details about the material being carried. The details are written down on a slip of paper written by a clerk at the source location. This slip contains information about the type of material, grade, quality, quantity, source, destination, truck number etc. At the time of loading from stack supervisor gives a slip to truck by mentioning Stack no. Grade Material and destination etc. then the truck proceeds to the weighbridge and hand over the slip to the weighbridge clerk who then enter the information into the ERP and also generate confirmation slip in duplicate (weight automatically captured directly from the weighbridge) is handed over to the truck driver. The truck after weighed at source proceeds to the tarpaulin cover spot where helpers cover the cargo area of the truck with tarpaulin. This is necessary to reduce spillage and also to prevent polluting the public access roads with fine dust. In rainy days, it also helps keep the ore dry.

Receipt at destinations

It is a process that on reaching the destination, the truck driver hands over the slip to the clerk at the destination weighbridge to crosscheck the source and destination weight. However, during rush times at the destination, in order to reduce the trip cycle time the weight is randomly crosschecked with the source weight. In both cases the control is by manually comparing the weight of source and destination. In absence of
the weighbridges at destination, weighment is not done and gross weight is recorded same as source weight.

The truck driver then proceeds to the unloading stack where a spotter gets the trip unloaded as per the ore parameters stamps one confirmation slip issued at destination and gives back to the driver for his records and retains one copy. Based on the retained copy the receipt of the trip is later confirmed in the ERP (this process of confirmation of the trip receipt is same for all destinations), leaving the process high and dry to know or capture reasons of difference in weight.

Enhanced (To Be) Process Map: for Short-haul Trucks

Figure 18: To Be Logistics Process Visual for Short-haul Road segment (with same Legends of Figure 8)

The enhanced process of short-haul envisaged usage of technology for identification of truck or its driver through the use of bio-metric (finger-print check) technology or any
other suitable technology intervention. There is not much of requirement to change the
process or controls, except that we must identify the truck to the extent possible, as
presently there is no control if the jetty handling contractor changes his fleet
composition any time, which may affect our load weight arriving computations due to
change of tare weight of new truck. The feasible technology options have been
discussed in next section, but here just to envision solution, we have visualized bio-
metric technology to conceptualize would be solution.

Short haul trips
In the proposed system, tagging is possible as per material grade location stack etc.
Further weighment process will be faster, this is possible by using RFID to improve
process time. For short trips where weighment is currently done, the process time is
reduced. For short trips where weighment is not done, weight is now captured for further
data analysis. Typically, no print out is generated for short trips. Estimated time taken in
proposed system:~6 sec.

In the proposed system, Barge Loading is also monitored using RFID system. The
barge loading begins with the shift supervisor entering the target weight (tons) for the
barge loading. Every truck on the jetty weigh bridge is then monitored, and the weight
noted down. Live data gives the supervisor information about how much tons have
already been loaded. Once the desired tons have been loaded, the signal lights turn
red, so no more loading happens.

Deployment phases
The proposed solution will be deployed in 2 phases namely a Pilot to be followed by an
enterprise wide deployment. The enterprise wide deployment will be rolled out for 3
months. In the pilot phase, we have installed RFID tags in 10 trucks, and run the system
from one source location to one destination location. Based on the lessons learnt, we
have begun architecting the solution for an enterprise wide roll out. In this rollout about
250 trucks are being covered across two locations. Next roll out shall cover the
remaining locations and trucks.

Enhanced (To Be) Process Map: for Long-haul Trucks
The new solution visualized for Long-haul trucks had to be re-engineered in a no. of ways as this was the most painful journey segment out of total end-to-end logistics process of ore supply chain. The existing process had a no. of lacunae in terms of long chaotic traffic queues at weighbridges and absolute free-wheeling of truckers while reporting to the destination, many of their trips were found missing in the company records due to flaws in the trip-recording process with no reliable back-up processes in place, in case of failure of main process due to some reasons. These too were being detected after a considerable time gap of 1-2 weeks, making it hard for everyone involved and also creating scope for manipulation and vested interests creeping in the system. Obviously then the reported losses were also high and it seemed as if everybody knew the problem, but no one could talk about the solution as it appeared a very big change with not much clue where to begin.

However after a no. of brainstorming sessions with all concerned, I could zero in on broad 3 features of proposed solution as follows: 1. all trucks need to be registered fresh with some unique master data fields, 2. The trucks need to be auto-identifiable at WBs enabling faster transactions without having the driver to get down from the truck for safety reasons, and 3. There has to be mandatory double weighment i.e. at source as well as destination. This last feature would be the most critical, not just to control losses but even to know missed trips, if any at the end of same day. The detailed coverage of selection of right technology and Envisioned Solution has been attempted in next section. However brief highlights and salient features of new solution is covered below.

- Bulk Raw-material loading and unloading data capture via RFID driven readers / handhelds and or through remote controlling of the WB PC’s through centralized control.
- Raw – material and processed material data capture and tracking via RFID
- RFID based tracking of road vehicles in transit.
- Automated weighing at weighbridge integrated with RFID.
- Controller based traffic light system for vehicle guidance at weigh bridge and security points
• ERP integration
• Dash boards
• Management Information Systems

Entry gate at source
In the proposed system, security at entry gate can be improved by monitoring the status of the RFID tags. If the tags report that the truck has not completed the last trip or if it has been flagged by a special supervisor while in the highways, or the tare weight is outdated, it is brought to the attention of the security personnel by an alarm. Such trucks are moved away from traffic and an inquiry is conducted offline.

Estimated time taken in proposed system: 4 ~ 6 seconds

Loading process
The trucks will be divided in groups (size and the number of groups to be decided as per the requirements). This groups will be allocated the destination and the material type so that the trip fields are common for a set of trucks and then include the Process of centralized control to write the details to the tag at the weighbridges and during the failure of the link to weighbridges the person will physically go to the weighbridge and incorporate the parameters, based on authorization.

Alternatively, an option will be provided to decide the data writing using handheld. This can be used by the supervisor to enter data (such as material type, source, destination etc) directly into the tag wirelessly. This operation can be done from a range of 25 meters, thereby improving safety conditions for the supervisor.

Estimated time taken in proposed system: 5 ~ 10 seconds

Weighment at source
At source Weigh Bridge, the driver need not get down from the truck as data is wirelessly transferred from the RFID tag to the computer at the weigh bridge office (only truck identification will be captured from tag and the material description will be written on tag on the basis of data fed from centralized location for that tag) . In future by using the Weigh-in-motion technology, the truck need not stop at the weigh bridge. The
weighment is done while the truck is in motion. Once the truck exits the weigh bridge, the RFID reader will write weighment information into the RFID tag. Optionally, a thermal printer may be placed on a pole to enable the driver to collect a print out with the trip details.

Estimated time taken in proposed system: 6 ~ 10 seconds

Tarpaulin cover at source

In the proposed system, alternately, the thermal printer can be placed at the tarpaulin cover spot. This will help reduce time taken at the weigh bridge further. The time taken by helpers to cover the tarpaulin is more than sufficient to generate a print out.

Estimated time taken in proposed system: 45 ~ 60 seconds

Exit gate at source

In the proposed system, security at exit gate can be improved by monitoring the status of the RFID tags. If the tags report that the truck is loaded and approved by a supervisor and weighment is done at Weigh Bridge, then it is alright to allow the truck to leave the premises. However, if there is any suspicion, an alarm is sounded to alert the security, who then physically verifies to make sure the truck is not making an un-authorized trip.

An alternate to issue the Print out at the exit gate

Estimated time taken in proposed system: 4 ~ 6 seconds. In case of print out at exit gate, the time taken will go up to approximately 30 ~ 45 seconds.

Travel to destination

During the travel to destination, the proposed system also allows a particular truck to be flagged while on the highway. This can be done using a handheld computer given to special supervisors. Trucks can be flagged for various reasons – if the supervisor suspects that a driver is under the influence of alcohol, or if the driver is driving in a rash manner or is indulging in pilferage/adulteration of material. Flagged trucks will be highlighted in the system at the destination entry gate.
For each type of transportation a maximum limit for transportation time will be fixed and whenever any truck is delaying the separate report can be taken out.

Entry gate at Destination
In the proposed system, security at entry gate can be improved by monitoring the status of the RFID tags. If the tags report that the truck is not plying an authorized trip, or has come to the wrong destination or if it has been flagged by a special supervisor while in the highways, or the trip has taken abnormally short or long time to reach the destination, it is brought to the attention of the security personnel by an alarm. Such trucks are moved away from traffic and an inquiry is conducted offline.

Estimated time taken in proposed system: 4 ~ 6 seconds

Weighment at destination
In the proposed system, the driver need not get down from the truck. Also, by using Weigh-in-motion technology, the truck need not park on the weigh bridge; the weighment is measured as the truck slowly moves on the weigh bridge. Also, a RFID reader mounted on a pole reads/writes data from/to the Tag about confirming the arrival of material at destination location. A thermal printer mounted on a pole will give a print out to the driver about trip confirmation. In case the tare weight is out of date, the print out mentions only the gross weight. For internal purposes, the tare weight will be taken soon after unloading, and that will be used to calculate the net weight. The print out will mention the lesser of the two weights (source & destination).

In case of any discrepancy (unacceptable difference in weight) in Gross weighment, an alarm is sounded in the weigh bridge office. The truck is taken offline for inquiry.

Estimated time taken in proposed system: 6 ~ 10 seconds

Tarpaulin uncover at destination
In the proposed system, alternately, the thermal printer can be placed at the tarpaulin uncover spot. This will help reduce time taken at the weigh bridge further. The time taken by helpers to uncover the tarpaulin is more than sufficient to generate a print out.

Estimated time taken in proposed system: 45 ~ 60 seconds
Unloading process
The truck then proceeds to the unloading stack. A supervisor directs the truck to the correct stack. The truck unloads the material. By giving a handheld computer to the supervisor, we can avoid the supervisor getting very close to the truck for checking the trip details thereby improving safety conditions.

Tare weighment
In the proposed system, for measuring the tare weight, the driver need not get down from the truck. The tare weight is written into the RFID tag wirelessly as well as stored in the ERP. In order to improve process efficiency, weigh-in-motion technology can be used optionally.

If this has to be done automatically, we need to organize trucks as groups (according to make/model of the truck). The tare weight then needs to be validated against the group’s tare weight. If there is a tare weight beyond the allowed tolerance (+/-), the tare weight is not stored and the hooter is sounded. Also if there is a difference in Tare weight between present recorded and last recorded more than specified limit, exception report has to be generated. Estimated time taken in proposed system: 6 ~ 10 seconds

Exit gate at destination
In the proposed system, security at exit gate can be improved by monitoring the RFID tags. Trucks are allowed to leave the premises only if the trip is closed (supervisor has confirmed the unloading process). Also, additional checks can be done for validity of tare weight. If tare weight is invalid, the truck will not be allowed to leave the premises until tare weight is updated, or an administrator approves the truck to leave the premises. All alarms have audio-visual indication using the hooter and traffic lights.

Estimated time taken in proposed system: 4 ~ 6 seconds.

4.9 As-Is and To-be Process Flow for River-cum-Sea
The general coverage of As-Is process flow of river-cum-sea segment has been discussed in earlier sections on industry and organization. However the key features of same is being reproduced here for quick re-collection: 1. The barges deployed for the
carriage of cargo were being monitored during their journey through mobile handsets given to crew members and once they reached at loading or unloading points, the same info was being captured manually by hand-written notes by the controlling supervisors as well as by the crew in their log-sheets. 2. At loading jetties, the count of short-haul trips for a particular barge trip was manual, but their weighment was automatic without identifying the truck, just recording weight in sequence. 3. There used to be no. of instances when the unloading end, especially the trans-shipper crew complained receipt of much lesser weight than recorded in boat note, but being a manual count of crane grabs by the stevedore supervisor, the same was never given importance and the unloading team at trans-shippers felt handicapped as not being able to prove their short receipt, being in mid-sea. The other unloading end was port berth for some trips, but here again the port authorities never listened nor agreed to officially share the weighment recorded at the belt-weighers installed on their stacker conveyor belt of berth no.9 citing that the same is only an indicative number for ascertaining crane operators’ productivity once a while and not for any official receipt or recording purposes, leading to unnecessary disputes. In short, the jetty and barge fleet supervisors always ruled high when it comes to ascertaining weights loaded on barges or while it was unloaded from barges. 4. This created suspicion in everyone’s mind, but the trans-shipper team, unfortunately being located in mid-sea most of the time, had developed indifference to the short receipt of cargo and in turn, many times they used to easily agree to give some extra cargo (at least 0.5-1.0% as said verbally to us during our dialogues) to the mother vessel at the demand of its master, without contesting the same through draft survey. This in turn gave rise to attitude of lethargy and indifference in the team responsible for Draft Survey measurements including 3rd party independent surveyors, who also gradually sung the song in sync and rhythm of trans-shipper teams of accepting everything fate-accompli.

**Enhanced (To Be) Process Map: for river-cum-sea segment**

As seen from above discussions, it was a free-for-all kind of atmosphere developed in this part of organization, diagnosed by me as
1. Primarily due to high-headed attitude of jetty loading teams. They should be made accountable for proving to their internal customers of river-fleet section that the cargo loaded in barge confirms to the accuracy it deserves and be ready to get the same witnessed with the customers jointly, to win their confidence. This becomes highly significant and important given the fact that unlike road, there is no double weighment possibility in this leg of water-borne journey and hence not only change of attitude, but even setting up right kind of weighbridge calibration schedules were the demands of new solution.

2. There was a clear need for automation of count of truck trips while loading the barge and the likely solution would be the one discussed in road short-haul segment earlier, reinforced with better user discipline and identifiable truck nos. to the extent possible to reduce margin of error.

3. The process of conducting Draft Survey needed a complete overhaul / strengthening for eliminating scope of likely error and authenticating the inherent technical elements of the same.

4. Attempting or inducing the behavioral change in river-fleet and Trans-shipper team for re-kindling their right to ask for delivery of correct quantity from jetty teams. This would also make them confident and feel empowered for contesting the potential conflict with masters of mother vessels through systematic conduct of draft survey, with the renewed confidence and support from jetty and river-fleet teams.

5. Finally the river-fleet team must be equipped with some monitoring tool for tracking the barges to make right decisions on allocation of cargo and better utilization of available barge capacity.

All above features have been dealt in next section under Envisioning Solution.

4.10 Selection of Technology

In the below section, I am not discussing all technology options, but only such technology interventions which have potential to resolve these problems after a deep
dive into these options and prima facie it looks feasible to implement them, basis mapping of To- Be of supply chain as covered in previous section of organization.

The proof-of-concept (POC) studies were conducted for following options basis literature review and above ‘As Is’ process mapping:

- Zigbee technology
- RFID – Active Tag with in-built memory
- RFID – Passive tag with in-built memory
- GPS (Global Positioning System) technology

Subsequent to this shortlisting, I had contacted a no. of technology solution providers across globe to get the POC conducted by them at the case company sites and basis this, some of them responded by asking their local counterparts i.e. alliance partner organizations to contact us.

Figure 13: Different manufacturers of RFID & Bar Code components

Bar Code India: Bar Code India Limited is a leading System Integration Service Provider in the field of AIDC (Bar Coding, RFID, Wireless and Mobile Computing) technologies.

Maxim: Maxim is a USD 2Billion company which designs, develops, and manufactures unique semiconductor products.

Motorola: Motorola’s RFID solutions enable businesses to a new level of efficiency by providing greater visibility into inventory as it moves across the supply chain.

RSI ID: RSI ID Technologies is a leading vertically integrated manufacturer of RFID antennas, inlays and tags.

Perceptron Software Labs, Bangalore: They represent Motorola and have developed middleware which might be suitable for our applications.
CMC Ltd., Hyderabad (subsidiary of Tata Consultancy Services): They are system integrators and have in-house strength of software development and integration with SAP.

With help from company executives, POCs were conducted for our road and river segments with their ready available hardware and software available with above 2 vendors shortlisted after conducting POCs with them and a few others.

Results of POC trials concluded that RFID with Passive tag technology with built-in memory (550kb) was the right choice for the trucks in road logistics i.e. for Long-haul and Short-haul trips. Similarly GPS technology was the best-fit for the barges in river segment due to business need of continuous track and trace feature, which was essential for a water-borne journey to be able to determine any route deviation of barge from the prescribed navigation channel by COP department due to sufficient water draft available in that zone and also for the safety reasons, as other vessels i.e. fishing trawlers or passenger crafts would not interfere in that navigation channel.

The figure below gives the broad technology interventions map for a typical mining industry processes / sections, which was shared with case company senior management and for our research purpose.
Let us now discuss salient features, practical and theoretical insights of these chosen technologies, so as to familiarize ourselves with finer technical details, for better understanding of the proposed solutions later. Let us first discuss basics of RFID i.e. Radio Frequency Identification Device technology and then GPS i.e. Global Positioning System.

The figure below gives a snapshot of both technological options for mining industry and we shall now discuss both in further detail.
Figure 15: Snapshot of RFID and GPS for mining supply chain

The first half of above figure illustrates use of RFID technology in Mining industry as a decision support system and second half of figure illustrates GPS based tracking system for asset turn-around analysis. Both if these technologies have been further explained in detail in the next section, one by one, first RFID and then GPS.

Figure 16: Different components of RFID technology

<table>
<thead>
<tr>
<th>Device</th>
<th>Model Name</th>
<th>Short Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Indicator Lights With Sound</td>
<td>RH-A\RK-A</td>
<td>Compact Revolving Indicator Lights with Sound</td>
</tr>
<tr>
<td>Indicator Lights Without Sound</td>
<td>RH-A\RK-A</td>
<td>Compact Revolving Indicator Lights</td>
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<td>-----------------------------</td>
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<td>----------------------------------------------------------------------------------------------------------------------------------</td>
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<td>Boom Barrier</td>
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</table>

4.11 RFID Technology for Road segment

Radio frequency identification (RFID) has been identified as one of the ten greatest contributory technologies of the twenty-first century and has received increased attention from practitioners and academics for its rapidly growing market. RFID is one of the most wanted technologies in todays’ large successful enterprises such as Wal-Mart, Dell, US Navy, Boeing, Ford, Michelin, UPS, DHL worldwide, and many others. RFID is part of a new generation of IT known as “contact-less communication” and the foundation of the “silent business” and “internet of things” (Yahia Zare Mehrjerdi, 2011).

Automatic identification and data acquisition is a pre-requisite for any voluminous supply chain or inventory case in any company before attempting any improvement on its bottom line. Large-scale adoption of RFID offers vast opportunities to reduce cost through better coordination between marketing and manufacturing. For instance, RFID can improve SC efficiency through real-time tracking, monitoring safety and overall warehouse operations, which leads to increase in sales volumes and improving profitability for suppliers and retailers. But these benefits of RFID implementation are not sustainable unless a number of issues impeding RFID adoption across organization are resolved immediately and meticulously.
There is not much of primary research to identify key benefits of RFID in Supply Chain Management and other industrial applications. This research through field studies is a step towards not only identifying such benefits, but even to prove them tangibly. To explore what these benefits are, published information on the RFID topic, as well as the success factors of related technology have been studied as covered under Literature Review Section of this thesis. RFID technology can be applied to various areas such as pharmaceutical industry, healthcare, logistics, retail, and security to name a few. Among these, the RFID technology has been increasingly used in SCM of logistics for the efficient management of short shelf life goods, container transport and automated delivery tracking system. All benefits calibrated and rationed to relevant context for this industry in different forms were discussed and debated with company management to get their perspective also. In this respect this research work attempts to study step-by-step implementation to serve as a guide to studying impacts of RFID on the supply chain of a large volume bulk ore export industry.

With the use of RFID technology and electromagnetic waves, users can send and receive data with no contacts occurring between interrogators and tags. Any RFID system consists of four main components as follows:

**Transponder / Tag**

An RFID tag is a microchip combined with an antenna and can be attached to any object to be tracked. The tag’s antenna picks up signals from an RFID reader/scanner and then returns the signal, usually with some additional data (like a unique serial number or other customized information). This would be commonly described henceforth as ‘capture’ meaning thereby ‘read and write’ capability of the tag. The tags which operate along 120-140 KHz frequencies are known as Low frequency tags, while high-frequency tags work along the 13.56 MHz and UHF tags work along the 850-900 MHz. Low-frequency tags are quite cheaper and need less power as compared to all other kinds of tags, while high and ultra-high tags have better range and faster data transfer.
RFID tags are capable to hold more information than data carrier systems such as barcode system. The four types of tags commonly available in industry are known as:

Passive tags;
Semi-passive tags;
Active tags and
Semi-active tags.

An active tag would need a battery to power it for both the chip and the transmission of data on the antenna, while Passive tags would get their power requirement from any remote RFID reader. Semi-passive tags use a small onboard battery to power the chip. Semi-active tags use the battery for powering the antenna but the chip relies on the RF energy from the reader (Potter, 2005). The life of active tags are limited while life of passive tags are unlimited. Active tags are heavier and costlier than passive tags.

**Antenna**

The antenna transmits and receives the signals to and from the tag. The quantity and type of antennas used depend on the application.

**Reader & Transceiver**

The reader directs the RF transceiver to transmit RF signals, receives the encoded signal from the tag through the RF transceiver, decodes the tag's identification and transmits the identification with any other data from the tag to the host computer. The user can change or customize the reader's operations to suit a specific requirement by issuing commands through the host computer or a local terminal. The RFID reader transmits an electromagnetic field that "wakes up" the tag and provides the power required for the tag to operate.

**Middleware**

This is the software that is customized based on the application of an RFID solution to integrate information for further use and analysis.
RFID systems work at a number of different frequencies including 125 KHz, 13.56 MHz, 2.45 GHz, and 5.8 GHz and for ultra-high frequency (UHF) 860-950 MHz.

**Specifications of Hardware used**

**RFID Reader**
- Operating Temperature: -40 °C to 80 °C
- Operating Humidity: 95% Non-condensing
- Multi-Detection: Yes read
- Detection Quantity: 30 tags/sec
- Gain: Adjustable
- Reader type: Passive

**RFID Tag**
- Operating Temperature: -40 °C to 80 °C
- Operating Humidity: 95% Non-condensing
- Multi-Detection: Yes read
- Gain: Adjustable
- Tag type: Passive
- Good for On-Metal Applications
- Tamper-proof with alarm
- 2.45GHz Microwave frequency
- 200-tag/sec identification rate, 2,000 tag management in RF field
- Reader communication is bi-directional providing commands including Addressing command and Stop Addressing Command.
- Tag orientation: Omni Directional
Hooter: Power 230VAC with IP65 casing, Audible sound in a noisy environment.

Traffic Lights: Relay Controlled, 2 color (Red & Green), Power 230VAC, IP65


The below tabular comparison explains salient characteristics of RFID versus Bar Code technology as well as different wireless sensing technologies. It is obvious that RFID is superior over Barcode and Passive RFID is more reliable than other technological options. The Solution designed with Passive RFID for tracking road logistics segment was called as Ore Tracking Solution (OTS) and we have discussed capabilities and features of OTS in detail after giving heads–up of comparative analysis of different technologies with RFID.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>RFID</th>
<th>Barcode</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hardware</td>
<td>Reader, tag</td>
<td>Reader, Sticker</td>
</tr>
<tr>
<td>Line of Sight</td>
<td>Not required (contact-less)</td>
<td>Required</td>
</tr>
<tr>
<td>Read Range</td>
<td>Passive UHF RFID:</td>
<td>Several inches up to several feet</td>
</tr>
<tr>
<td></td>
<td>- Up to 40 feet (fixed readers)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Up to 20 feet (handheld readers)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Active RFID:</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Up to 100’s of feet or more</td>
<td></td>
</tr>
<tr>
<td>Read Rate</td>
<td>10’s, 100’s or 1000’s simultaneously</td>
<td>Only one at a time</td>
</tr>
<tr>
<td>Identification</td>
<td>Can uniquely identify each item/asset tagged.</td>
<td>Most barcodes only identify the type of item (UPC Code) but not uniquely.</td>
</tr>
<tr>
<td>Read/Write</td>
<td>Many RFID tags are Read/Write</td>
<td>Read only</td>
</tr>
<tr>
<td>Technology</td>
<td>RF (Radio Frequency)</td>
<td>Optical (Laser)</td>
</tr>
<tr>
<td>Interference</td>
<td>Like the TSA (Transportation Security Administration), some RFID frequencies don't like Metal and Liquids. They can interfere with some RF Frequencies.</td>
<td>Obstructed barcodes cannot be read (dirt covering barcode, torn barcode, etc.)</td>
</tr>
<tr>
<td>Automation</td>
<td>Most &quot;fixed&quot; readers don't require human involvement to collect data (automated)</td>
<td>Most barcode scanners require a human to operate (labor intensive)</td>
</tr>
<tr>
<td>-----------</td>
<td>---------------------------------------------------------------------------------</td>
<td>---------------------------------------------------------------</td>
</tr>
</tbody>
</table>

Table 2: Comparative Analysis of RFID and Bar Technology

Below table gives a further heads-update of various technology options within wireless sensing technologies i.e. Active RFID, Passive RFID and Zigbee, on key parameters which may be considered critical to most practical applications and it is obvious that Passive RFID has highest reliability and least chance of mis-function of tag. Hence we have chosen the passive RF technology option while designing and developing new solution called Ore Tracking Solution (OTS). The passive tag also offer non-interference in case of multiple tags in vicinity, due to its limited range, unlike longer distances in case of active tags.

<table>
<thead>
<tr>
<th>Wireless Sensing Technologies</th>
<th>RFID</th>
<th>ZigBee</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power</td>
<td>Battery operated</td>
<td>Battery operated</td>
</tr>
<tr>
<td>Energization</td>
<td>Radiative</td>
<td>Radiative</td>
</tr>
<tr>
<td>Frequency Range</td>
<td>2.446 - 2.454GHz</td>
<td>858 - 930 MHz</td>
</tr>
<tr>
<td>Communication Range</td>
<td>Long range (70+ m)</td>
<td>upto 6m</td>
</tr>
<tr>
<td>Read Multiple tags</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Per Tag Cost</td>
<td>High tag costs</td>
<td>Low</td>
</tr>
<tr>
<td>Tag Size</td>
<td>Varies depending on application, mostly bulky</td>
<td>button to credit card size, compact</td>
</tr>
<tr>
<td>Fixed Infrastructure Costs</td>
<td>Lower (RFID Reader costs)</td>
<td>Higher (RFID Reader costs)</td>
</tr>
<tr>
<td>Recurring costs</td>
<td>Average (battery replacement)</td>
<td>Low</td>
</tr>
<tr>
<td>Avg. time taken for 20 appearances</td>
<td>5 seconds</td>
<td>7 seconds</td>
</tr>
<tr>
<td>Read and write time from 2 mtrs.</td>
<td>5-8 sec</td>
<td>7-10 sec</td>
</tr>
<tr>
<td>signals Interference of nearby trucks</td>
<td>very high, may require manual overrides</td>
<td>negligible, controllable</td>
</tr>
<tr>
<td>Max. Memory available with Tag</td>
<td>Anything theoretically, 3MB currently</td>
<td>Max 1MB currently, 512bits standard</td>
</tr>
</tbody>
</table>

Max 256KB presently
<table>
<thead>
<tr>
<th>Need for battery replacement</th>
<th>every 1-2 years</th>
<th>Not Applicable</th>
<th>Not Applicable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Failure or mis-function of tag</td>
<td>Higher chances</td>
<td>Very Low possibility</td>
<td>Low possibility</td>
</tr>
</tbody>
</table>

Table 3: Comparative features of various wireless technologies

4.12 Solution Envisioning for Road Segment

Basis To-Be processes, capabilities of proposed RFID based Ore Tracking Solution (OTS) would be as follows:

**Touch Point Capabilities**

The Touch Point Module of the OTS can be a loading point, destination point or any intermediate point (like security gate). This will allow the user to

- Capture arrival date/time of the truck.
- Capture loading information like material, loading machine code, item code etc.
- Capture loaded weight of the truck by interfacing the OTS with Weighbridge.
- Capture loaded truck details.
- Automate some of the linked data like warehouse, trip number etc.
- Upload the gathered data into the existing ERP server database.

**Weighbridge Adaptor Capability**

The OTS used this adaptor for communicating with the weighbridge, automatically capturing the weight once the truck arrives at any touch point.

**Process Validation Capability**

The OTS included the business validation rules such as identifying incomplete trips, late coming trucks, weight variation etc., which will be applied at every point of the process to ensure healthy work flow.

**ERP Capability**

OTS is equipped with an adaptor to communicate with the ERP server for automatically uploading of data into the ERP server.

**Indication Lights Capability**

OTS have the ability to drive the indicator lights based on the status of the processing of each truck. Based on the status of completion of the truck data processing indicator of different colors will be switched ON/OFF. This will indicate the driver if he can move the place or to wait for some more time.
**Biometric Interface Capability**
OTS would have the ability to interact with the Biometric readers for ensuring the valid drivers (through registered fingerprints) are driving the trucks.

![Image of Component and Features of OTS](image)

The following subsection documents the contexts of the OTS in terms of significant externals with which it interacts. OTS interacts with many external systems which make it a single point solution for optimizing the whole process of data handling in the industry.

**Brief description of RF based OTS system**

**For Long haul Trips:** RFID tags would be permanently installed on the trucks. This tag would help the system in identifying a truck easily. RFID tagging would be used to accurately describe the material, quantity and quality associated at weighbridge, storage, processing, and distribution or delivery points. The data would be input to RFID tags on vehicles at pick up or source points (such as mines, weighbridges or processing areas) with wireless handheld readers or fixed readers to record actual data, eliminate mistakes and unidentified items. Thus, a lot of data entry would be eliminated as the tag carries the data in digital form, which could be easily used at various points. Also, by eliminating the need for the driver to get down from the truck at weigh bridges, further time is saved. RF readers mounted at strategic locations in combination with software applications are used to communicate, check & authenticate information on RF Tags for
pilferage or missing quantities and prevent errors by matching data from pick up points through delivery.

Dedicated local area network connectivity and software solutions link the material & logistics identification systems with enterprise applications to eliminate data latency and to gain real-time visibility and control.

**For Short-haul Trips (Barge Loading module):**

In this module, the weighbridge module RF-tagged trucks would be loaded by a wheel loader and would reach to a weigh bridge near the jetty. Once the weight is captured through RF tag or Auto-Id, the trucks reverse on the jetty and unload the material onto the barge parked below the loading bridge. In special cases, a truck having come on the jetty might be asked to return without loading the material on the barge (e.g. the material may be of wrong grade or barge has taken requisite cargo load). There will be a special supervisor provision to cancel this trip (for the barge load calculation purpose) and at the same time maintain this trip for payment to the truck contractor. The trucks would keep coming in queue basis the quantity to be loaded in that barge and the weight of all such truck trips with Truck-id or Auto-Id would get associated to the particular barge for which the weighbridge module was opened with the first truck trip. In this manner, the OTS system not only records the number of truck trips, but even the weight of these trips to compute the total cargo weight loaded in a particular barge.

This module has been designed with flexibility to accommodate integration with GPS based Barge Monitoring System.

**4.13 GPS Technology for River-cum-Sea segment**

The Global Positioning System (GPS) is a satellite-based radio-navigation system, originally established by the U.S. Department of Defense for military positioning applications. It has been made available to the civilian community as a by-product. The credit of successful application of GPS technology in civilian community goes to integration of its Navigation and surveying features with Geographic Information Systems (GIS). GPS is a complex system which can achieve position accuracies ranging from 100 m to a few millimeters (critical for missile applications) depending on
the equipment used and procedures followed. The higher accuracies would demand higher costs and more complex observation and processing procedures. However in industry applications, it is important for users to understand which techniques are required to achieve desired accuracies with the minimal cost and complexity. The objective of this brief coverage is to provide historical development background and procedural information needed to effectively use GPS technology in our industry application.

- First satellite launched in 1978.
- Fully operational system declared in April, 1995
- System has been made available to the civilian community.

US President Ronald Reagan issued a directive that guaranteed that GPS signals would be available at no charge to the world after the tragic downing of Korean Flight 007 in 1983 - a tragedy that might have been prevented had its crew access to better navigational tools. This directive helped open up a commercial market. The number of civilian and military users kept growing as the deployment of GPS continued at a steady pace through the 1990s. Public awareness about GPS exploded during the Persian Gulf War in 1991.

A heads-up broad comparison of RFID and GPS technologies is given below, with GPS broken into GPS Satellite and GPS Cellular (as being used in our research study).

Table 4: Considerations in use of technology for tracking of Barges

<table>
<thead>
<tr>
<th>Device</th>
<th>GPS – Satellite</th>
<th>GPS - Cellular</th>
<th>RFID – local</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coverage</td>
<td>Worldwide</td>
<td>Cellular network</td>
<td>Facility</td>
</tr>
<tr>
<td>Intervals</td>
<td>1 to 24 times per day</td>
<td>Every 1 – 10 minutes</td>
<td>Based on activity</td>
</tr>
<tr>
<td>Installation</td>
<td>No wire</td>
<td>No wire</td>
<td>Facility to be</td>
</tr>
</tbody>
</table>
### Application Areas

<table>
<thead>
<tr>
<th>Applied Areas</th>
<th>Sky, water, Land</th>
<th>Sky, water, Land</th>
<th>Land</th>
</tr>
</thead>
<tbody>
<tr>
<td>Application</td>
<td>No power equipment</td>
<td>Fleet vehicles</td>
<td>Inventory</td>
</tr>
<tr>
<td></td>
<td>Container tracking</td>
<td>Powered equipment</td>
<td>Access control</td>
</tr>
<tr>
<td></td>
<td>Sensor monitoring</td>
<td>Remote monitoring</td>
<td>Fleet management</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Medical</td>
</tr>
</tbody>
</table>

#### Navigation with GPS

Navigation, in a broader sense, can refer to any skill or study that involves the determination of Position and Direction. Navigation is a field of study that focuses on the process of monitoring and controlling the movement of a craft or vehicle from one place to another, which is possible through the specialized knowledge used by navigators to perform navigation tasks. The field of navigation includes four general categories: land navigation, marine navigation, aeronautic navigation, and space navigation. All
navigational techniques involve locating the navigator's position compared to known locations or patterns. In this sense, navigation includes orienteering and pedestrian navigation. All the Elements required for navigation is possible in GPS with an addition of time which further makes this technology interesting for commercial applications. GPS is able to give us

- Location (altitude, latitude and Longitude)
- Distance
- Speed

GPS system is broadly divided into three segments:

- The space segment - satellites which broadcast radio signals toward users on the Earth and in turn, receive commands from the ground.
- The Control segment - monitors the space segment and send commands to satellites through control room set-up on ground.
- The User segment - receives, records and interprets the radio signals broadcast by the satellites.

GPS satellites broadcast signals from space, and each GPS receiver on ground uses these signals to calculate its three-dimensional location (latitude, longitude, and altitude) and the current time.

The space segment is composed of 24 satellites in medium Earth orbit and also includes the payload adapters to the boosters required to launch them into orbit. The satellites are distributed in a manner that ensures at least four satellites are visible almost anywhere in the world at any time as shown in Figure. Each satellite receives and stores information from the control segment, maintains very accurate time through on-board precise atomic clocks and transmits signals to the earth.

The ground control segment operates the satellite system on an on-going basis. It consists of five tracking stations distributed around the earth. The control segment is composed of a master control station, alternate master control stations, and a host of dedicated and shared ground antennas and monitor stations to ensure that all satellites
are functioning properly and computes their position in space. Whenever a satellite is not operating properly, the ground control segment may set the satellite as "unhealthy" and apply such measures as may be necessary to correct the problem. In which case, the satellite should not be used for positioning until its status is brought back to "healthy". The computed positions of the satellites are used to derive parameters, which in turn are used to predict where the satellites will be later in time. These parameters are uploaded from the control segment to the satellites and are referred to as broadcast ephemerides.

The user segment includes all those who use GPS tracking equipment to receive GPS signals to satisfy specific positioning requirements. A wide range of equipment designed to receive GPS signals is available commercially, to fulfil an even wider range of user applications. Almost all GPS tracking equipment have the same basic components: an antenna, an RF (radio frequency) section, a microprocessor, a control and display unit (CDU), a recording device, and a power supply. These components may be individual units, integrated as one unit, or partially integrated. Usually all components, with the exception of the antenna, are grouped together and referred to as a receiver. In fact some GPS receivers being marketed now consist only of computer cards which may be mounted in portable computers or integrated with other navigation systems.
4.14 Solution Envisioning for River-cum-Sea segment

Basis our earlier discussions on To-Be processes, capabilities of GPS technology based system for river-cum-sea segment would be as follows:

Any GPS system has four basic capabilities, which are converted into different applications:

- Position and coordinates;
- Distance and direction Measurements;
- Travel progress reports;
- Accurate time measurement.

These capabilities are turned up into successful applications in various sectors including Military Applications such as

- Search and rescue
- Disaster relief
- Surveying, Marine, aeronautical and terrestrial navigation
- Remote controlled vehicle and robot guidance
- Satellite positioning and tracking
- Shipping
- Geographic Information Systems (GIS)
- Recreation

We attempted to develop an integrated web-based solution (termed as Barge Monitoring System – BMS, explained in detail in later sections) to schedule, Monitor & optimize real-time 24X7 movement of barges from multiple loading and unloading stations, which helped company in:

- Reduction in turnaround time of barges
- Real-time visibility of Ore in transit with estimated arrival info
- Reduction in demurrage of mother vessels
- Downtime reduction of barges
- Enabled real–time coordination between key stakeholders

**Brief description of BMS solution** -- All the barges would be fitted with on-board GPS module, called BMU, by taking power supply from the storage battery of the barges. Each BMU would be assigned a unique number, which would be linked to a particular barge and this data would be maintained in the barge master, including static information of the barge such as name, registration number, carrying capacity and permissible draft as per marked RLL –restricted load line and certified by authorities, its due dates for validity / renewal of survey and details of allocated crew, if any. All the routes would be geo-fenced and important landmark, especially the important sandbars,
would be geo-tagged to facilitate easy referencing. The navigation channel as prescribed by COP office would also be marked on the GIS module, so as to know if the crew had deviated from prescribed route at any point of time. The destination such as port berths and jetties would also be geo-tagged, whilst the trans-shippers and mother vessels would be providing their coordinates (latitude and longitude) wherever they would be anchored.

Although the BMS module per se has been discussed in greater detail in next chapter. However it would be worth discussing some of the most salient point of this solution development. Unlike RFID based OTS solution for road segment, the BMS solution did not have any scope for business process re-engineering, nor had any challenges of integration with 3rd party machines (like weigh bridge in OTS). Hence I decided to explore avenues for enriching the software solution with some unique first of its kind features as discussed below. The first and foremost was ETA feature incorporating the ‘Tide tables’ (set of calendar based tide timings released by Captain of Port office, the administrative authority for regulating barges plying in river and sea). This feature enables users to know the expected time of arrival of barge at any selected location duly considering the likely delay if any due to low tide, thus helping them plan or assign barge dynamically for scheduling. Similarly another unique feature was conceived to build appropriate linear programming optimizer tool in BMS to help control-user decide what is best way to utilize a barge under given set of assumptions, constraints and desired objective. This optimizer feature would be of great significance for any company involving multiple under-loading vessels with a large barge fleet, especially under self-ownership model, so as to achieve best-in-class operational efficiency and overall effectiveness of sea loading process. Besides these advantages, it would also serve as excellent training and development tool for imparting operational and supervisory skills in staff deployed for overseeing operations. These systems together would allow users to decide allocation of barges dynamically in real-time environment to various jetties and trans-shippers (source and destination combination) for achieving an objective in a given set of situation such as:
• To achieve best-in-class turn-around time for the barge by choosing best source and destination location both, with least waiting / idle time and high throughput of loading / unloading rate.

• To achieve least cost of operation by choosing a source which can ensure maximum permissible loading cargo qty. depending upon the prevailing tide draft at jetties.

• To divert any existing / nearby barge or allocate a new barge to a destination depending upon its need for cargo, subject to its historical or current performance, with a view to save upon demurrage cost of mother vessel.

• To stack – up a pool of barges of required cargo tonnage as and when the vessel is nearing its completion so as to avoid demurrage for want of a small cargo falling short nearing the end of vessel loading.

The above list of situations are just a sample example and there could be a no. of many more innumerable practical business scenario, which the control desk or river-fleet supervisor would face and be expected to resolve during the day. There is no guarantee that any human being would take all decisions logically at all times, especially in a complex and multi-variable operations’ scenario (transportation matrix). This is where I have conceptualized the optimizer solution and the challenge would be to fine-tune it in such a manner that same would be handy for resolving all kinds of future scenario.