6.1 Brief Introduction: This kind of developmental research work in industry necessitates a systematic step-by-step approach in all phases of work i.e. bench study of constituent processes, conduct of POCs and pilot field trials, followed by live implementation, refined data acquisition and finally data compilation and analysis of results. Finally once convinced with the results, one has to scale up the real-life implementation across all asset locations / sites. This is also explained in below schematic diagram:

Figure 27: Schematic Representation of Pilot Methodology for Developmental Research

It also demands a great amount of conviction and patience while collaborating with executives of case company for suggesting alternatives as to what would not cause interruption in their normal conduct of business, so as to continue getting their cooperation. The research scholar faced a number of other obstacles, the most important being lack of requisite field infrastructure (to name a few for instance, power connection in vast open mining lands for operating any electronic gadgets, appropriate lay-outs with wider roads and lane discipline amongst truckers near the weighbridges to facilitate ease in handling traffic in case of unintended delay while installing any new process / equipment). However I am happy to note that with pursuance and collaborative approach, all hurdles were overcome successfully and the outcome was more than satisfying as was evident from the acceptance of solution from company management and their decision to roll-out the new solution for scaling it up across all locations.

The final data output was compiled, tabulated and processed using various mathematical, industrial engineering and statistical tools as was appropriate in consultation with industry and subject experts. I had tried to collate and incorporate in relevant software as would be seen later through screenshots, all possible important reports using various analysis tools including Dashboards through pictorial presentations to support KPI analysis for higher management. Let us now ponder over
the complete methodology of data collection and then discuss data analysis in the later part.

Following step-by-step milestones were conceptualized for a systematic methodology up to live real-life implementation to be ready for collection of data and analysis of the same to discuss findings:

- Conduct and conclude Proof-of-concept studies for various technological options (as done earlier to freeze selection of technology for each segment).
- Appointing System Integrator for frozen technology choices for road and river segment.
- Pilot studies in each segment / chosen option to comprehend future challenges in actual roll-out and finding quick resolutions to them.
- Ordering of hardware & middleware with requisite site infrastructure installation.
- Design and development of Application Software.
- Field testing for optimization of results and User Training of Application Software.
- Live Roll-out, commence Data Acquisitions and control progress through resolving daily challenges of internal controls for concurrent system improvements.

Data Analysis and Finding

The entire workflow from source to destination is to be managed with a software application suite that has options to perform various tasks at handheld, weigh bridge pc, entry / exit gates etc. The software must be designed in a manner that allows flexibility and easy adaption to company’s business processes as envisaged and discussed earlier.

6.2 Undertaking Pilot Studies

Pilot studies for each technology were then conducted for a set of trucks and barges on specific routes which gave us an opportunity to fine-tune all logistics processes so as to enable performing faster and accurate transactions. Such pilot studies for road and
river-cum-sea segment gave us opportunity to visualize real-life difficulties and dilemma, to examine likely gaps in our solution envisioning process as well as likely difficulties or challenges we would be facing in capturing transactions or in deciding the set of instructions to be given to operations’ staff under apparently conflicting objectives in a given scenario. Thus pilot studies gave me a lot of insights in actual process in both segments and a peep-through window to pitfalls in as-is process and how the to-be process should be designed to make them fool-proof from human errors.

6.3 Ordering of Hardware, Middleware and Site Infrastructure Installation

Now the necessary financial and administrative sanctions were sought from the company management for implementing the chosen technology options consequent to presentation and discussions on the offerings by respective vendors. Usually a system integrator agency is mandated by the technology provider (hardware manufacturer) who in turn, is expected to install hardware and deploy necessary middleware developed by them in consultation with hardware manufacturer for best results. Therefore important role of such agency is to fine-tune/optimise the performance of hardware vis-à-vis their middleware, so as to ensure accurate yet fast data capture, the most crucial part of any automation process. The bill of materials included hardware requirements like readers, antenna and tags with stickers to be affixed on trucks or would be welded to the truck body in case of any challenge in pasting the stickers. The proposed solution would need certain infrastructure including desktop computers, a database server, thermal printers, pole for mounting the RFID reader, red/green signal lights and alarm hooters for entry and exit gates etc. A complete list of such infrastructure was made available, was ordered and procured before installing them appropriately. Due to the harsh environment of mounting the tags/readers in the open, it was necessary that the tags and readers comply with IP65 standards, especially related to:

- Splash proof (to protect against rain/water washing of truck cabins)
- Dust proof
- Vibration withstanding
- Tamper proof mounting.
6.4 Design and Development of Application Software

For any automation and/or information technology project to succeed in real-life situation, it mandates a very carefully designed system inputs and data processing logic by undertaking a system requirement study (SRS). The data inputs have to be visualized considering the information requirement of transactions and business decisions. In order to ensure sanctity and hygiene of input data, one has to perform validations before accepting any such inputs or processed intermediate values. Necessary Logic and Flow Diagrams (only important ones being shared here) were finalized to develop system design for application software for various business processes of road segment as explained below.

As regards the development of end-user application software (AS), either the system integrator himself or a separate software developer agency would be mandated by him to work in parallel with company executives and others involved with implementation. In our case, we were fortunate that both system integrating agencies (for RFID and for GPS) agreed to take up the application software development work by themselves and thus avoiding the need for a 3rd party software developer, eliminating need of additional coordination.

Both agencies, after receiving order from company, deployed their expert system design teams for finalizing key user requirements and developing necessary software and reports as necessary to monitor the performance. The initial As-Is and envisioned To-Be process-mapping attempted earlier were shared with them to expedite the development work. In the below section, we would briefly describe the RFID system as envisaged for our implementation and the OTS application software developed by the integrator agency. Likewise we would also discuss GPS system and BMS application software.

6.5 RFID-based Cargo Management System (OTS)
The application software (AS) development was undertaken in parallel with ordering and installation of hardware & middleware at site. It was also decided to follow modular approach in developing the AS so that the same could be tested in the field as and when its parts (modules) were ready and due modifications (incl. removal of bugs, if any) may be incorporated. The final version of full AS was tested in the live field for its intended functioning along with middleware. We would now briefly discuss each of the two systems in further details.

**OTS** - Similarly a new Ore Tracking Software (OTS) was developed for capturing and tracking road transportation transactions. The salient features of this software included truck-tag identification process as well as automatic recording of truck weight directly from the weighbridge controller unit, in conjunction with guiding traffic light system. The capabilities and features of OTS have been discussed earlier while envisioning To-Be solution for road segment and we would discuss more in-depth the various logic diagrams after attempting business process re-engineering, leading to system design and development for a human touch-free or least-possible human interference.

RFID technology needs to be leveraged to achieve fast wireless transactions between weigh bridge PC and the trucks. This is achieved by fitting RFID tags on the trucks and placing RFID readers connected to the weigh bridge PCs. Additional RFID readers may be placed later at security entry and exit gates. The next few pages contain a few
reproductions of Logic Flow Diagrams for different stages of road segment logistics. E.g. the first Logic diagram covers existing logistics process validations of weighment of road trucks for long haul. The next few logic diagrams in sequence show the validations and check-points of loading point at source, at destination location, tare weighment and intermediate touch point like security gates. Each of such validations were discussed and vetted with case company officials and a flexibility was built in the system design to make them modifiable basis customer requirement in future under different business applications. These Logic flow diagrams include new validations introduced in the system in order to make it more and more automatic and reduce human interference / dependency so as to reduce / eliminate human errors and thus increase system data reliability. The data integrity and hygiene is crucial in such automation exercise, since these data points would provide the necessary business decisions-support system.

One must also keep in mind the fine balance between data validations and speed of transactions / decisions, that every time a validation is performed, the speed of overall system should not get unduly affected. This can be achieved by careful examination of data, data structure and its storage / retrieval speed. The frequently used data can therefore be stored in relational data tables in such a manner that these are accessible at faster speed and are indexed every time a new data gets added. Similarly if a particular data or a set of parameters are frequently used in a user-demanded query or report, then the same can be stored in easily accessible cache memory location and / or such similar location for a faster data processing per needs of the user.

Validations in Supply Chain Processes of Road segment

Existing Process (As Is):
Existing validations in Supply Chain Process (As Is)
Figure 20: New Processes: Loading Point Validations in OTS
Destination Point Validations in OTS
Figure 21: Destination Point Validations in OTS

Tare Weight Point Validations in OTS
Figure 22: Tare Weight Point Validations in OTS
Intermediate Touch Point Validations in OTS (Security Gate Entry)

Figure 23: Intermediate Touch Point Validations in OTS (Security Gate Entry)

Each of the business processes designed had to be tested in a controlled environment, called Test Bench on a development server and the same was migrated to production server later after the beta-test for an error-free run in the field. The logic flow diagrams
reproduced below represent new important sample ones for the road segment, however the river segment did not involve new ones.

**End-User Training for road segment OTS:** The new OTS Application Software implementation necessitated imparting extensive user training to a cross-section of weigh bridge operators, security personnel and logistics planning teams at source and destination locations each. This was the key phase of our implementation as this part of handling of trucks (drivers) in road segment was the most challenging, as it used to be very chaotic many times, during the solution testing phase. Since this solution was highly automatic and sequential in terms of guiding traffic light system, it took a while to adopt because the truck drivers and weighbridge operators were tuned to earlier process of high manual intervention and hence they would interrupt manually due to lack of patience.

This made the solution development team to make it very robust by making system ignore any command from operator till it was not ready in all respects of sequential process. Finally the solution in its final shape was asking operator to only press ‘ENTER’ command, if he was okay with all the data displayed on the system including weight or reject it, for sending the truck to system manager for detailed diagnosis of error, if any. This was hugely appreciated by one and all as it had met all business hygiene requirements of internal controls as well as the time to capture transaction also was greatly reduced, much to everyone’s pleasant surprise.

The data of all trips performed by tagged trucks during the subsequent 3 months were recorded with unique trip-id allotted automatically by the application software. The automatic data capture for RFID had been attempted till +99% level was achieved and the data were uploaded to the company server through utility programs developed by company’s IT personnel.

Data structure consisted of following fields for long-haul trips between Source and Destination:

- Truck no. / Id
• Tare Wt.
• Gross Wt.
• Net Wt.
• Date and Time
• Reader-Id / Location

Data structure consisted of following fields for short-haul trips for loading barges:

• Barge name
• Reader-Id / Location
• Truck-Id
• Gross Wt.
• Net Wt.
• Date and Time
• Total Wt. loaded in barge

The RFID software developers of the system integrator had a tough time when the Company made it mandatory for the RFID system to read all weights directly from the weighbridge, necessitating the integration of RFID solution with 3rd party WB vendor and further stressed the need of integrating all transactions to the ERP in use. However these tough demands of integration gave birth to 2 distinct advantages as it forced us to explore conduct of Business Process Re-engineering (BPR) while designing the new system and this attempt was a huge success, almost like ‘Eureka’ kind of experience in the company as explained in following paragraph.

Automating the capture of truck weight without human intervention (keying-in) -- A huge hygiene factor for the industry as there were a no. of past incidences wherein weighbridge operators had connived with truckers to record erratic and fake weights,
thereby increasing the handling losses in actual practice / inventory physical assessment, coupled with higher accounts payable for freight. However this achievement did not come cheap as software development team toiled hard with 3rd party WB vendor team to develop and test the new algorithm solution to trigger arrival of stable weight after elapse of few seconds once the truck enters weighbridge platform. This further necessitated installation of traffic lights (red always, turn to green on capture) on all weighbridges to trigger completion of weighment and to communicate the truck driver to leave the weighbridge / proceed. The only thing a weighbridge operator was required to do was to press ‘enter’ command on the keyboard once he sees display of the truck-id followed by its weight (gross or tare as the case may be). This has been explained earlier how chaotic situation prevailed during testing phase of this solution when truck drivers would not maintain lane discipline, making it tough for the security personnel.

**Introduction of ‘AUTO-ID’ for Short-haul truck trips**

Having reduced the effort of weighbridge operator considerably, the software development team toyed with an excellent proposition of ‘auto-id’ feature wherein even if RFID system misses to identify a particular tag (and hence the truck), it would still capture the weight as sensed from weigh bridge algorithm recording this trip as Auto-id trip. Thus it gave huge opportunity to company of eliminating the need to man the internal weighbridges installed on the jetties and thus all such weighbridge operators were immediately re-deployed on other jobs like traffic enforcement for road segment trucks on arrival weighbridges at jetty inward gates, which got streamlined later with rigid road furniture to maintain lane discipline amongst truckers. At that stage the company posted these operators at key traffic junction points en-route as On-the-Road Assistance staff for similar discipline enforcement which we believe, can further reduce turn-around time for truckers thus enabling higher transport volume for company.

Basic reasoning of deployment of Auto-Id solution only on internal jetty movement trucks was that the payment basis as envisaged in engagement contract was the tonnage loaded in the barge and hence it was not necessary to recognize individual truck-id, but the total no. of trips and weight thereof, since all trucks were belonging to
one contractor working within a closed boundary for short-hauls. Unlike short-hauls, Auto-Id solution was not suitable for road segment long-haul trucks as these trucks belonged to individual owners, not to a particular contractor and were operating in a wider area outside the boundary of one premises, thus it was necessary to recognize accounts payable for each individual truck id.

It is worth mention here that barge loading jetties in Goa have 2 different configurations i.e. one where weigh bridge is mounted on the loading bridge itself and the other where weigh bridge is mounted along the route before loading bridge. Hence it can be observed that the first configuration has distinct feature of enabling gross and tare weighment i.e. (before and after tippling contents) while truck is on loading bridge, whereas in the 2nd configuration only gross weight is extracted, since the tipper trucks have to go for weighment at en-route weighbridge, thereby consuming extra time in each gross and tare weighment (as a normal practice, most such configurations take only gross and do consider same tare weight for each truck as done once in a day or shift, just to avoid loss of time as almost all trucks deployed on this internal movement within that jetty are fixed for whole season). This whole set of new software termed as Auto-Id software became the unique solution for software developers as well, who perceived this as a huge business opportunity to roll out for other jetty owners, considering direct saving of manpower while streamlining basis of their accounts payables to truckers.

External Hardware

- Weighbridge
  - Is the weighbridge installed by company at all the relevant points of mines wherever there is capturing of weight?
  - In order to exploit the interfacing of OTS with weighbridges, company should make sure the same is calibrated and is in working condition.
- Client Workstation
• Is the computer installed by company at all the places wherever RFID devices are being installed?
• This would be the computer over which the RFID software would be installed which will drive the whole OTS.

• Network
  • Internet connectivity provided by SGL for communicating the data gathered to with the ERP server.

External Software
• MS Office
  • MS Excel will be used for generating the reports
  • MS Access will be used as local application database
• Browser
  • Latest version of Internet Explorer
• .net 3.5 Framework
  • Required platform for running the RFID software

Capabilities of OTS
This subsection provides a high-level overview of major capabilities of the OTS. Note that this subsection provides useful information for understanding the following requirements, but does not contain specific testable requirements.

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 module 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.
• Automate the process of issuing the driver’s slip.
• Upload the gathered data into the existing ERP server database.

Weighbridge Adaptor Capability
The OTS would be enabled with the adaptor for communicating with the weighbridge. This adaptor automatically captures the weight once the truck arrives at any touch point.

Process Validation Capability
The OTS would include the business validation rules which would be applied at every point of the process to ensure healthy workflow. Some of such validation would include identifying the incomplete trips, late coming trucks, weight variation etc.

ERP Capability
OTS would be equipped with an adaptor to communicate with the ERP server. After the data gathering at every point, after a specified amount of time, the data would be automatically uploaded into the ERP server.

Indication Lights Capability
OTS would 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 would be switched ON\OFF. This would 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 are driving the trucks.

Reports and Alerts of OTS system:
Since all the OTS data were synchronised with the company’s ERP, it was conveyed to users to expect and use their existing reports / methods to generate reports and
queries, in order to avoid duplication of efforts. However since some of the query and reports would be frequently asked by users as well as we too would be monitoring and analysing the data, it was thought fit to deploy Crystal Reports software to help generate following reports:

**Trip Summary Report**
This report gives summary of trips loaded per location for a given date range (1 day or 1 week), for example:

<table>
<thead>
<tr>
<th>Location</th>
<th>Sub-location</th>
<th>Number of trips</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cxyz</td>
<td>Plant stack</td>
<td>20</td>
</tr>
</tbody>
</table>

**Loading Summary Report**
This report gives summary of material loaded per location for a given date range from ddmmyy to ddmmyy, e.g.:

<table>
<thead>
<tr>
<th>Location</th>
<th>Material</th>
<th>Weight (tons)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cxyz</td>
<td>Fe60</td>
<td>200</td>
</tr>
<tr>
<td>Sxxa</td>
<td>Fe58</td>
<td>150</td>
</tr>
</tbody>
</table>

**Recipient Summary Report**
This report gives material received per location for a given date range:

<table>
<thead>
<tr>
<th>Location</th>
<th>Material</th>
<th>Weight (tons)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cxyz</td>
<td>Fe60</td>
<td>200</td>
</tr>
<tr>
<td>Sxxa</td>
<td>Fe58</td>
<td>150</td>
</tr>
</tbody>
</table>
Loading time delay report
This report gives the time difference between loading and weighbridge for a given date range e.g.:

<table>
<thead>
<tr>
<th>Trip #</th>
<th>Truck</th>
<th>Time difference (minutes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CUWB10001</td>
<td>H876</td>
<td>15</td>
</tr>
<tr>
<td>CUWB10020</td>
<td>H805</td>
<td>10</td>
</tr>
</tbody>
</table>

Loaded, but not weighed report
This report gives list of trips that were loaded, but not weighed for a given date range e.g.:

<table>
<thead>
<tr>
<th>Location</th>
<th>Trip #</th>
<th>Truck</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cxyz</td>
<td>CUWB10001</td>
<td>H876</td>
</tr>
<tr>
<td>Sxxa</td>
<td>CUWB10020</td>
<td>H805</td>
</tr>
</tbody>
</table>

Trend of trucks without Tare weighment
This report gives the list of trucks without tare weight for a given date range:

<table>
<thead>
<tr>
<th>Location</th>
<th>Trip #</th>
<th>Truck</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cxyz</td>
<td>CUWB10001</td>
<td>H876</td>
</tr>
<tr>
<td>Sxxa</td>
<td>CUWB10020</td>
<td>H805</td>
</tr>
</tbody>
</table>

Trip time duration report
This report gives us trip time duration for a given date range between a set of source and destination pair or a combination thereof e.g.:

<table>
<thead>
<tr>
<th>Trip ID</th>
<th>Source</th>
<th>Destination</th>
<th>Time duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>CUWB10001</td>
<td>Cxyz</td>
<td>Aabcd</td>
<td>25 mins</td>
</tr>
<tr>
<td>CUWB10020</td>
<td>Sxxa</td>
<td>Xmat</td>
<td>23 mins</td>
</tr>
</tbody>
</table>
**Truck exception report**
This report gives the exceptions (undelivered trips, weight difference) for a given date range.

<table>
<thead>
<tr>
<th>Trip ID</th>
<th>Truck #</th>
<th>Exception Type</th>
<th>Exception data</th>
</tr>
</thead>
<tbody>
<tr>
<td>CUWB10001</td>
<td>H876</td>
<td>Undelivered</td>
<td></td>
</tr>
<tr>
<td>CUWB10020</td>
<td>H805</td>
<td>Net Weight Short</td>
<td>-300kg</td>
</tr>
<tr>
<td>CUWB10021</td>
<td>H801</td>
<td>Tare weight Diff.</td>
<td>+200 kg</td>
</tr>
</tbody>
</table>

**Weight variation summary report**
This report gives the material-wise variation in weight for each destination for a given date range and can be further drilled down to all trucks of a particular location:

<table>
<thead>
<tr>
<th>Location</th>
<th>Material</th>
<th>Short</th>
<th>Excess</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cxvz</td>
<td>Fe60</td>
<td>-5000kg</td>
<td>+3000kg</td>
</tr>
<tr>
<td>Sxxa</td>
<td>Fe58</td>
<td>-800kg</td>
<td>+1500kg</td>
</tr>
</tbody>
</table>

**Weighbridge analysis report**
This report compares the weigh bridges at source and destination for a given date range and can be drilled further for all readings leading to Avg Diff.:

<table>
<thead>
<tr>
<th>Source WB</th>
<th>Destination WB</th>
<th>Avg. diff</th>
</tr>
</thead>
<tbody>
<tr>
<td>CUWB1</td>
<td>AMWB3</td>
<td>-100kg</td>
</tr>
<tr>
<td>CUWB1</td>
<td>AMWB4</td>
<td>-150kg</td>
</tr>
</tbody>
</table>

**Material in transit report**
This report gives the material-in-transit data (current status). No need to give date range). The source can be further drilled down for all trucks appearing under that
destination combination to enable user to select those trucks for posting missing entry if the time duration has crossed transit guarantee days.

<table>
<thead>
<tr>
<th>Source</th>
<th>Destination</th>
<th>Material</th>
<th>Weight (tons)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sxxa</td>
<td>Cxam</td>
<td>Fe58</td>
<td>2000</td>
</tr>
<tr>
<td>Cxyz</td>
<td>Amet</td>
<td>Fe60</td>
<td>2300</td>
</tr>
</tbody>
</table>

**Trucks not weighed at destination report**
This report gives list of trucks not weighed at destination for a given date range due to weighbridge not being available, to enable forced posting of source weight, only if the security gate entry and exit record exists in OTS. In case of no record exists, the same would appear as in-transit in above report.

<table>
<thead>
<tr>
<th>Trip ID</th>
<th>Truck #</th>
</tr>
</thead>
<tbody>
<tr>
<td>CUWB10001</td>
<td>H876</td>
</tr>
<tr>
<td>CUWB10020</td>
<td>H805</td>
</tr>
</tbody>
</table>

**ERP Integration**
The database masters were populated from the company’s ERP database at the start and later any further changes in ERP were automatically copied over to the OTS database through a scheduled program. All trip data (long haul trips and short haul trips) were being synchronized into the ERP in real-time as well as all ERP Sync would be happening subject to availability of server connectivity at each location.

**Business Continuity Plans**
This section details the business continuity plan in case of any failure of equipment.

Network connectivity failure

- Normal operations will continue in offline mode
- In case of assigning new jobs to groups (of trucks), it has to be done manually at the WB PC
• Data will be stored in weighbridge PC and synchronized upon restoration of network connectivity

RFID Reader failure

• Replace with spare from inventory
• Continue with manual mode of operation (manually create trips)
• In manual mode, shift supervisor can enter all data except weight, which will be taken automatically from the weigh bridge.

RFID Tag failure

• Replace tag with spare from inventory
• Continue with manual mode of operation till replacement
• In manual mode, shift supervisor can enter all data except weight
• In other places, shift supervisor will have to manually select the truck from the selection list.

PC failure or Power failure

• PC failure can be due to various reasons from virus problem to machine not booting.
• Power failure means there is no electricity and UPS has run out of battery
• Shut down that weigh bridge, and divert traffic to other weigh bridges
• In case it is not possible to divert traffic to weigh bridge, keep readily available backup PC CPUs. These CPUs can be quickly connected and booted to resume the operation.

6.6 Barge Monitoring System (BMS) for River segment

When we embarked upon developing GPS based application software, the integrator agency offered us to use the pre-developed solution architecture with configuration of additional data processing demands for enabling network optimizing features. It was
evaluated that their proposed solution was a plain vanilla modular one and was comparatively much simpler than RFID as there were no demands of change in business process in the new software design. In fact it was also found that the proposed software had a no. of such standard reports which need to be customized to a minor extent by way of nomenclature of key fields, except that we needed to conceptualize the dynamic barge allocation optimizer. It was then conceived that we could incorporate ‘tide tables’ and build a transportation algorithm-based Linear programming application, which would have to be run every time a key constraint would change or any of the objectives were changed. This led to development and testing of such application software.

A new Barge Monitoring control room desk was conceptualized assisted by the software incorporating network optimization tools and dynamic barge assignment module to help control desk manning team to know ‘ETA’ (i.e. Expected Time of Arrival) with ‘What-If ’ kind of analysis / computations. This helped team to guide and push barge masters / drivers much ahead in their journey (during loaded sail or during empty sail) to cross those sand bars (i.e. hurdle points) within the tide timings for the day. This also helped control desk team to monitor and take disciplinary action against erring barge crew members if anyone attempted to cross the sand bar earlier than prescribed time of tide, thus running the risk of ‘barge grounding’.

Extensive user training was provided to control desk team and across implementing jetty locations, for gaining hands-on experience of newly developed application software (BMS) during and after testing phase. The Control Desk Supervisors were trained with technical and behavioral orientation to act as a super-boss who was watching everything to facilitate moral policing of the barge crew and jetty staff (excepting trans-shipper crew who did not require much monitoring supervision being better qualified and objectively engaged). This helped achieve the purpose as the crew / jetty staff now knew that there were means by which actual reasons of their under-performance could possibly be traced with evidence, unlike the past when nobody could even verify their whereabouts, leave apart the reasons further.
Let us now discuss briefly the salient features of Barge Monitoring Software, which was deployed for automating the river-cum-sea segment processes to collect the data from live barge trips being made for ship loading / port berth.

**Features of BMS:**

- An integrated web-based solution to schedule and monitor & optimize in real time movement of barges from various loading and unloading destinations with quantity of cargo loaded and grade carried out on 24X7.
- BMS is a Web Based System and can be accessed through the URL on intranet / Internet with sample dump screen shots shown below. Some critical transaction of the BMS application could also be accessed on Handheld Devices, if required.

**BMS** consisted of following:

- On-board Device (BMU)
- Mobile Data Terminal for loading / unloading Points
- Web based BMS Application Software
- Dynamic Optimization Software
- Interface with existing ERP / MIS system
- Local Area Network (LAN) / Wide Area Network (WAN)

**BMS Application and GIS server module:**

- Replay and analyse the routes traversed by the barges from the database on a map for post-monitoring.
- Generation of reports as per customer defined formats
- Performance Statements for a particular barge over a defined period
- Duration of the barge in use
- Route travelled by the barge
- Exception reports on missed trips, completed trips, exceptions of idle time, engine ignition off status etc.
Details of Barge arrival / departure at specified loading / unloading / Trans-shippers points

Duration of stoppage / Halt at predefined location, more than a user defined period.

**Mounted GPS Unit (BMU- BARGE MONITORING UNIT):**
The barges were fitted with the GPS Unit. The BMU unit compiles the GPS position, Speed & time data and transmits it at a pre-defined interval using GSM / GPRS communication in real time. In case of zones where GSM/GPRS connectivity is not there unit stores the data in memory and sends it on reaching connectivity.

**Communication Server Software:**
The Communication Server acquires the data sent by BMU units over GSM / GPRS and updates it to the BMS database.
The visual shown below is a screen dump of BMS designed and developed:
BMS SOLUTION ARCHITECTURE:

Communication Server (CS) software primarily provides the data communications link between Database and the BMU units for the management of the vehicles equipped with GPS devices computes the current position information based on GPS data. It also sends Destination and other messages to the BMU unit for display on the LCD Display in BMU units.

An integrated web-based solution to schedule and monitor & optimize in real time movement of barges from various loading and unloading destinations with quantity of cargo loaded and grade carried out on 24X7.

BMS is a Web Based System and can be accessed through the URL on intranet / Internet with sample dump screen shots shown below. Some critical transaction of the BMS application could also be accessed on Handheld Devices, if required.
Components of BMS Application:

BMS application has following components:

- **Barge Tracking and Monitoring System**: It uses the position and time data received from BMU units along with other user entered data of events (web based / Mobile devices) like barge loading / unloading start / end, Barges shut out, barge on spot / long-term hiring etc. It displays the position and Operational KPI’s of Barges in real-time on the GIS map of Mandovi and Zuari River.

- **Automated Barge Assignment**: BMS has a dynamic optimization system which analyses all the real-time events GPS and user events and computes the ETA of all Barges while considering constraints like high tide, low tide etc. It then analyses
the information of vessel loading, cargo contribution plan of jetties and other constraints to generate an optimized destination for barges for user to accept or edit depending upon situation prevailing with user. It records such user changes to reflect sub-optimized decisions taken by users.

- Reporting and Dashboards. – This system carries out reporting on KPI’s and alerts using the dashboards and detailed reporting using the reporting tool.

- Alerts : BMS system generated alerts as given below
  - Barge going to unscheduled destination.
  - Barge stopping more than defined period of time at any location
  - Barges not reaching jetty / unloader on time
  - Barge loading / unloading in progress & barge is moving
  - Unscheduled Barges
  - Alerts for non-working BMU units.
  - No cargo / no barge situated at unloaders / jetty.

- BMS–SAP interface: This system ensures that all required events and transaction are posted to SAP in real-time. It also manages synchronization of master data from SAP to BMS.

Sample Reports and Dashboards

- Jetty Performance Report
- Barge Performance Report
- Trip Cycle Analysis Report
- Loading Unloading Summary report
- Barge Reallocation Report & Cargo Redeployment Report
- Idling Analysis report - Loading and Unloading Points
- Ship Wise Performance
- Ship Wise Cargo Analysis Report
- Shut Out Cargo Report
- Delivery Slip of Ore to Harbour
- Vessel Wise Handling Loss Report
Figure 30: Barge Position in real-time on GIS Map below

Figure 31: Dynamic Status of Barges (below)
Time lost due to Tide Report

<table>
<thead>
<tr>
<th>Time Lost Due To Tide</th>
<th>Time Lost Due To Tide</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Date</th>
<th>Barge Name</th>
<th>Trip No.</th>
<th>Loading Point</th>
<th>Load Barge</th>
<th>Loading Time</th>
<th>Unloading Time</th>
<th>ETA at Unloading Point</th>
<th>Tide</th>
</tr>
</thead>
<tbody>
<tr>
<td>06/03/2012</td>
<td>JAY/CR70XA</td>
<td>409</td>
<td>Santorin</td>
<td>05/03/2012</td>
<td>06:00</td>
<td>10:00</td>
<td>10:30</td>
<td>0.00</td>
</tr>
<tr>
<td>06/03/2012</td>
<td>JAY/CR70XA</td>
<td>410</td>
<td>Santorin</td>
<td>05/03/2012</td>
<td>11:30</td>
<td>06:00</td>
<td>10:30</td>
<td>0.00</td>
</tr>
<tr>
<td>06/03/2012</td>
<td>JAY/CR70XA</td>
<td>412</td>
<td>santorin</td>
<td>06/03/2012</td>
<td>06:00</td>
<td>12:00</td>
<td>11:30</td>
<td>0.00</td>
</tr>
<tr>
<td>06/03/2012</td>
<td>JAY/CR70XA</td>
<td>472</td>
<td>Santorin</td>
<td>06/03/2012</td>
<td>15:30</td>
<td>05:45</td>
<td>11:30</td>
<td>0.00</td>
</tr>
</tbody>
</table>
Trip Cycle Analysis

Barge Performance Report

Table 5: Sample BMS Reports (above)

Barge Master Performance Report
## Vessel Wise Barge Loading

<table>
<thead>
<tr>
<th>From Date</th>
<th>To Date</th>
<th>Vessel Name</th>
<th>Quantity Loaded</th>
<th>Grade</th>
<th>Loading Commenced</th>
<th>Loading Completed</th>
<th>Unload Per Vessel</th>
<th>Unloading Commenced</th>
<th>Unloading Completed</th>
<th>Unload Qty</th>
</tr>
</thead>
<tbody>
<tr>
<td>09/03/2011 07:30:00</td>
<td>12/03/2012 07:30:00</td>
<td>VAISHI V</td>
<td>1585.00</td>
<td>68</td>
<td>17/01/2012 17:45:00</td>
<td>17/01/2012 19:10:00</td>
<td>VAISHI</td>
<td>17/01/2012 21:40:30</td>
<td>18/01/2012 03:34:31</td>
<td>1880.00</td>
</tr>
<tr>
<td>09/03/2011 07:30:00</td>
<td>12/03/2012 07:30:00</td>
<td>ATHENIAN PHOENIX</td>
<td>2116.00</td>
<td>61</td>
<td>17/01/2012 18:00:00</td>
<td>17/01/2012 20:40:00</td>
<td>ATHENIAN PHOENIX</td>
<td>18/01/2012 02:30:00</td>
<td>18/01/2012 04:25:03</td>
<td>2116.00</td>
</tr>
<tr>
<td>09/03/2011 07:30:00</td>
<td>12/03/2012 07:30:00</td>
<td>MODER</td>
<td>781.00</td>
<td>64</td>
<td>17/01/2012 21:00:00</td>
<td>17/01/2012 23:40:00</td>
<td>MODER</td>
<td>18/01/2012 01:00:00</td>
<td>18/01/2012 03:00:00</td>
<td>781.00</td>
</tr>
<tr>
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<td>12/03/2012 07:30:00</td>
<td>TORN</td>
<td>1181.00</td>
<td>83</td>
<td>18/01/2012 02:00:00</td>
<td>18/01/2012 04:00:30</td>
<td>TORN</td>
<td>18/01/2012 04:00:30</td>
<td>18/01/2012 06:00:16</td>
<td>1181.00</td>
</tr>
<tr>
<td>09/03/2011 07:30:00</td>
<td>12/03/2012 07:30:00</td>
<td>TORN ORIENT</td>
<td>2203.00</td>
<td>88</td>
<td>17/01/2012 22:30:00</td>
<td>18/01/2012 00:30:00</td>
<td>TORN ORIENT</td>
<td>18/01/2012 06:30:58</td>
<td>18/01/2012 08:30:00</td>
<td>2203.00</td>
</tr>
<tr>
<td>09/03/2011 07:30:00</td>
<td>12/03/2012 07:30:00</td>
<td>MODENA</td>
<td>2111.00</td>
<td>88</td>
<td>18/01/2012 02:00:00</td>
<td>18/01/2012 04:00:30</td>
<td>MODENA</td>
<td>18/01/2012 04:00:30</td>
<td>18/01/2012 06:00:09</td>
<td>2111.00</td>
</tr>
<tr>
<td>09/03/2011 07:30:00</td>
<td>12/03/2012 07:30:00</td>
<td>ATHENIAN PHOENIX</td>
<td>2386.00</td>
<td>61</td>
<td>17/01/2012 21:00:00</td>
<td>17/01/2012 23:00:00</td>
<td>ATHENIAN PHOENIX</td>
<td>18/01/2012 10:50:34</td>
<td>18/01/2012 13:20:06</td>
<td>2386.00</td>
</tr>
<tr>
<td>09/03/2011 07:30:00</td>
<td>12/03/2012 07:30:00</td>
<td>MODER</td>
<td>2100.00</td>
<td>88</td>
<td>17/01/2012 16:00:00</td>
<td>17/01/2012 18:00:00</td>
<td>MODER</td>
<td>18/01/2012 12:10:10</td>
<td>18/01/2012 12:10:10</td>
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<td>12/03/2012 07:30:00</td>
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<td>1888.00</td>
<td>87</td>
<td>17/01/2012 21:00:00</td>
<td>17/01/2012 23:00:00</td>
<td>MODA ROSARIO</td>
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<td>1888.00</td>
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<td>18/01/2012 04:00:00</td>
<td>VAISHI</td>
<td>18/01/2012 04:00:00</td>
<td>18/01/2012 06:00:08</td>
<td>2144.00</td>
</tr>
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<td>12/03/2012 07:30:00</td>
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<td>2302.00</td>
<td>84</td>
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<td>18/01/2012 23:00:00</td>
<td>REVIL</td>
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<td>2302.00</td>
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<td>87</td>
<td>17/01/2012 21:00:00</td>
<td>17/01/2012 23:00:00</td>
<td>MODA ROSARIO</td>
<td>18/01/2012 12:40:30</td>
<td>18/01/2012 14:40:30</td>
<td>2306.00</td>
</tr>
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<td>12/03/2012 07:30:00</td>
<td>TORN ORIENT</td>
<td>1728.00</td>
<td>88</td>
<td>18/01/2012 02:00:00</td>
<td>18/01/2012 04:00:00</td>
<td>TORN ORIENT</td>
<td>18/01/2012 10:10:14</td>
<td>18/01/2012 12:10:14</td>
<td>1728.00</td>
</tr>
<tr>
<td>09/03/2011 07:30:00</td>
<td>12/03/2012 07:30:00</td>
<td>MODER</td>
<td>1311.00</td>
<td>84</td>
<td>18/01/2012 02:00:00</td>
<td>18/01/2012 04:00:00</td>
<td>MODER</td>
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<td>18/01/2012 17:05:43</td>
<td>1311.00</td>
</tr>
<tr>
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<td>12/03/2012 07:30:00</td>
<td>MODA ROSARIO</td>
<td>1822.00</td>
<td>87</td>
<td>18/01/2012 21:00:00</td>
<td>18/01/2012 23:00:00</td>
<td>MODA ROSARIO</td>
<td>18/01/2012 12:40:30</td>
<td>18/01/2012 14:40:30</td>
<td>1822.00</td>
</tr>
<tr>
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<td>12/03/2012 07:30:00</td>
<td>TORN ORIENT</td>
<td>2194.00</td>
<td>88</td>
<td>18/01/2012 02:00:00</td>
<td>18/01/2012 04:00:00</td>
<td>TORN ORIENT</td>
<td>18/01/2012 17:10:13</td>
<td>18/01/2012 19:30:31</td>
<td>2194.00</td>
</tr>
</tbody>
</table>
Alerts Sample: Alert Type - choice screen

SMS based Enquiry / Alert system:

SMS Enquiry of Barge Position / Status in Real Time

SMS Query / Request - e.g. Status : Barge XXXX

SMS Query’s Reply
Barge: XXXX
16-08-2013 14:23:23 T - Cust: YY
Location: Crossed Vivashand Setu
ETA: Karachi: 17-08-2013 04:30

Customer / Barge Operator

Data from RFID

Client PC

Communication Server

Database Server

Web & Application Server

Barge Monitoring System - Data Center
Sample Dashboards

Figure 32: Sample Dashboards of BMS application software
6.7 Live Roll-out, Data Acquisitions and Full-scale Implementation

Before rolling out full-scale implementation, sufficient training inputs as explained earlier were imparted to the operating, control desk and security personnel of the chosen locations as they were made responsible to supervise the recording of continuous capture of data extending up to 3 months in coordination with me and the system integrator team. The data of all trips performed by the dedicated trucks or barges were recorded for each unique trip-id as allotted automatically by the application software. These data were then subjected to scrutiny for their completeness and were then uploaded to company’s ERP system through the utility programs developed by company’s own IT personnel.

It is pertinent to bring it to attention here that the initial RF data capture (auto) remained only around 90.0 percent which was further enhanced by installing additional nos. of antenna to above 99% consistently (& beyond on many days) so as to avoid manual entries. The only manual intervention / effort left intentionally for RF system was to the extent of punching information such as material grade and the stack from / to where material was loaded / unloaded. The rest of all the data were captured automatically by RF-based OTS system including the source / destination location with particular weighbridge (derived from the reader-id) and likewise by BMS system for barges and trans-shipper.

It would be worth mention here that while all data were being captured in the system, the strong query and report system helped team for ensuring simultaneous micro-level field action by way of identifying the delayed-arriving trucks or barges and taking corrective action basis cross-examination of truck drivers by security team or of barge crew by control desk team, to sensitize the overall echo system about our renewed focus and commitment on transaction time improvement. There was a visible change in the way company executives and truck drivers / transporters / barge crew were responding to the demands of new system as they were eager, being unaware of the outcome. But soon they understood the new systems were responsive.
The **road segment** need to be covered in more details throughout this research thesis, as it had involved quite a few new business processes due to additional controls and logical validations built-in the OTS application software. Some of the changed processes are being described below:

**Grouping of trucks**

In order to improve logistics, trucks had to be organized as groups, and each group will be assigned a job. A job was defined as a set of trip parameters (Source, Destination, Material Type etc.). Once the groups and jobs were set up, whenever a truck arrived at the source weigh bridge, the software would automatically create a trip with unique Id, using the preconfigured parameters. A new job (meaning a new trip) could be assigned to the group only if previous job was done, meaning the trip was closed by destination entry in the system.

**Weigh bridge process**

Due to the placement of the linear antenna, traffic on the weigh bridge was allowed in only one direction. Truck drivers were trained to drive slowly on the weigh bridges. They were advised to pay attention to the red / green traffic signal placed at the end of weighbridge, as they were supposed to move out of weighbridge only when the light turned green.

The manual hand-written paperwork process was replaced by print-outs from the thermal printer placed near the driver's window on a pole, which on later part of implementation, shifted to a separate documentation center near to the tarpaulin cover yard and drivers were asked to collect the same from there during / after tarpaulin coverage.

**Entry / Exit gates**

In As-Is process, there was no checking done by the security personnel. The new process involved performing regular checking as well as responding to alarms raised by the system. However due to lack of sufficient strength of security personnel, company
had asked us to skip this check as they relied more on the weighbridge with double
weighment being made compulsory for all trucks.

**Permission Matrix**

In order to protect the security of the application, certain operations needed to be
performed only by designated users. This matrix captures all the permissions given to various roles.

<table>
<thead>
<tr>
<th>Operation</th>
<th>Security</th>
<th>Supervisor</th>
<th>Shift supervisor</th>
<th>Local Admin</th>
</tr>
</thead>
<tbody>
<tr>
<td>Out of turn close trip</td>
<td></td>
<td></td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Out of turn cancel trip. In extraordinary circumstances, it may be required to CANCEL a trip, without having to deliver the material at the destination.</td>
<td></td>
<td></td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Out of turn modify trip. Modification includes changes to Source, Destination and Material Type</td>
<td></td>
<td></td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Flagging (for rash driving or DUI)</td>
<td></td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Unflagging (based on Critical, Major, Minor)</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Complain (Truck left without weighment)</td>
<td>Yes</td>
<td>Yes</td>
<td></td>
<td>Yes</td>
</tr>
<tr>
<td>Start trip (on handheld)</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Start trip (on WB PC)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Configure the truck groups</td>
<td></td>
<td>Yes</td>
<td></td>
<td>Yes</td>
</tr>
<tr>
<td>Accept weight differences (in case of conflict) but with flag</td>
<td></td>
<td>Yes</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>Tare weight</td>
<td></td>
<td>Yes</td>
<td></td>
<td>Yes</td>
</tr>
<tr>
<td>Close trip (on handheld)</td>
<td></td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Close trip (on WB PC)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Start Barge loading</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stop Barge loading</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Configure site settings</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
The live roll-out involved a no. of challenges as there were multiple fronts now open and a no. of users were involved to be guided, directed and communicated for keeping a close vigil on operations. While the road segment worked only during the day hours, the river-cum-sea segment used to work 24*7 and hence it demanded a more close vigil on the events taking place due to close coordination demands of barges and trans-shipper operations.

The most challenging situation faced in the road segment was related to achieving a high capture rate in the beginning days of go-live, when the drivers would get down from the trucks at the weighbridge despite our clear instructions for in-situ weighment and get guided by traffic lights turning green. But they were curious to know as well as were not ready to leave weighbridge despite seeing green light, to insist for getting challan-cum-weighment print-out as was the practice earlier, although same was shifted to a new documentation center close to tarpaulin cover yard.