Connected Automation®

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SUMMARY

Today's railroads tend to adopt control technologies in a somewhat piecemeal fashion. The discrete application of a single technology solution may be effective within its defined mission, but more consideration must be given to the interaction of applications when defining an integrated systems approach. This paper will describe a layered approach to integrate existing control technologies with enhanced train detection/location capabilities and multiple methods of operator interface to improve classification yard efficiencies, enhance worker safety, and set the groundwork for highly optimized and coordinated Train-Engine-Car-Crew (TECC) resource movement.

Recent advances in data communication, sensor networks and mission critical central control systems have contributed to the advent of command and control platforms capable of supporting integrated rail yard automation applications. Command, Control, Communication and information (C3i) systems operate somewhat analogously to the Computer Aided Dispatch systems for mainline train control. Integrated yard automation systems address coordinated control of key locations within the yard, while optimizing and minimizing the movement of all mobile assets, referred to as TECC resources. Control of field devices including switches, derails and any other protection device are coordinated in relation to the location and assigned activity of all TECC resources within the yard facility. A seven-layer approach to building an integrated automation infrastructure to support dozens of productivity, safety and efficiency applications is presented.

1. CURRENT TECHNOLOGY: THE HUMP AND RCL

Automation of the rail yard has been traditionally centered on the hump control system, a real-time process control system used to automate the classification of an inbound train's cars into a series of blocks. These blocks will later be assembled into outbound trains. The hump control system has removed the bottleneck from the car classification process, but naturally the bottleneck has shifted to other operating areas within the yard.

Another recent automation application involves the construction of Wi-Fi wireless data communication networks to support car maintenance and inspection reporting. The networks provide worker connectivity from mobile PDA devices in the field to the central car management database. Applications supported in the Wi-Fi network tend to be driven by the car and engine mechanical departments, and less so by the transportation departments. This would appear to be an ideal backbone communication network to connect multiple future applications, as this paper will discuss.

Over the past several years, capital investment in the yard has been directed to the implementation of Remote Control Locomotive (RCL) technology. Remote control locomotive systems allow a single crew member to switch cars. Remote Control Locomotive (RCL) technology has been applied to some identified "choke" locations with varying degrees of success.

Because of the widespread implementation of RCL technology, there have been several advances in complementary yard automation systems, with continued focus on productivity improvement and the inherent and measurable gains in safety. Due to increasing demands for greater yard throughput and scheduled operations, coupled with more moving pieces, with fewer people to move the pieces, the necessity for integrated automation and optimization technologies is rapidly emerging. It is now becoming critically important to plan and coordinate movement in the car classification process by linking the hump control system, the RCL equipment, the Wi-Fi car management networks and other remote controlled equipment into a network of connected, managed and optimized nodes.

2. NEXT GENERATION YARD AUTOMATION

Railroads evaluate yard productivity through various measures including number of cars processed; number of received trains handled; number of new trains built; and average time a car resides at a specified terminal location, also referred to as the Terminal Dwell Time. Railroads strive to decrease dwell time by continually measuring the dwell time variable[1] and by attempting to create a "fluid" car movement pattern. Creating fluidity requires strategic planning and balancing all moving assets to decrease dwell times and improve throughput throughout all related yards.

Multiple track configuration and car movement scenarios can be evaluated through off-line planning simulators, which will provide theoretical performance metrics to compare the different scenarios. Sometimes the optimized result of the simulation is implemented in production, and then Time-Motion` studies can be performed to measure the accuracy of the optimized result under actual operating conditions. Through either actual measurement or simulated conditions, railroads continue to identify critical "choke" points within yards, and have begun to apply the first layers of Integrated Automation (IA) to create the fluidity they require.

Railroad operators have begun to deploy automation technology to these choke point locations, but the deployment is on a rather ad hoc basis. Whereas the piecemeal application of automation has proven beneficial, with rapid return on investment, there is little to no consideration regarding the potential linking of these automation systems to generate fluid and optimized solutions.

However there are now proven technologies available railroads can use to create well planned and integrated control systems, and unlock layers of beneficial application to create a planned, scheduled and optimized operation.

3. INTEGRATED RAIL YARD AUTOMATION

Mission critical, software-based Command, Control, Communication and Information (C3i) systems provide the operating platform for Integrated Automation (IA) applications. Integrated Automation refers to the logical integration of two or more traditionally separate control functions. For example, linking RCL functionality with the ability to line a route from the RCL's operator control unit will achieve a certain level of integrated automation, with associated safety and productivity gains.

Safety gains are achieved by limiting the number of times a crew member needs to climb on and off the train to line switches. This will produce a measurable improvement in the number of tripping injuries, one of the greatest areas of injury in the yard operation[2]

Productivity will also be improved from the time saved by eliminating the manual operation of lining a switch. When the majority of manual tasks are reduced to a few automated sequences, the aggregate time savings in switching a yard can be significant.

The previous example is a single integration of two completely separate functions. While technically feasible to accomplish this single result, the integration should be properly planned within the defined framework of fully integrated rail yard automation (IA) systems. This framework will provide a layered application approach to define the functional interface between each planned application, and provide a Productivity Roadmap to ensure return on investment is identified and achieved as each application layer is actuated.

A layered application framework will begin with building the IA infrastructure, including powered switches, powered derails, flagging/blocking devices, track circuits or equivalent, data communications network, and a mission critical, software-based Command, Control, Communication and Information (C3i) system. From this basic IA infrastructure, the following seven application layers can be deployed:

3.1. <u>Layer 1: Control</u>

Remote control of an individual power switch, derail device or any equipped flagging or blocking devices; control a series of routes, automatically block tracks for car inspections. These types of remote control systems are actively being applied to choke points on an ad hoc basis, and have delivered significant return on invested capital.

3.2. <u>Layer 2: Protect</u>

This layer provides protection of crew from unblocked tracks and RCL moves; protect shove track moves and calculate real-time distance to couple messages. Layer 2 systems are also in production use today, but again they typically stand-alone and are not planned as part of TraIntegrated Automation architecture.

3.3. Layer 3: Track TECC

All mobile resources (TECC) can be tracked and protected in the yard. Provides enhanced worker protection, dynamic map of car location, and eventual coordination of car movements. This is accomplished through the creation of a train detection network of track circuits. Train detection technologies are mature, and in widespread use.

Layer 3 contemplates networking train detectors and applying computer algorithms to refine the ability to track and follow individual elements moving throughout the tracked environment. There are only a few systems in service today that accomplish this goal, but with increased adoption of the Integrated Automation model, the networked train tracking system will become the primary enabling component.

3.4. Layer 4: Coordinate

Intra-departmental coordination is realized through real-time work order communication through new and existing Wi-Fi wireless data communication networks. The Wi-Fi network will become the local yard backbone to communicate to and from all connected equipment. There exists today a few PDA (Personal Digital Assistant) applications to automate some functions, but this is an area where productivity and business management tools will flourish once the Integrated Automation platform is constructed.

3.5. Layer 5: Optimize

Optimization today is primarily a result of the application of strategic planners that simulate certain historical operating parameters. The proposition in deploying the seven layer IA architecture is to convert the off-line, strategic planners into real-time, tactical planners. The tactical planner will provide rapid analysis of the effect of exceptions to the strategic plan. Decisions made to address any exception are best handled by an experienced employee. But no matter how experienced the employee, the decision will be primarily based on the local (meaning yard) effect the decision produces, and not the systemic effect. With real-time, tactical analysis it will be possible for solutions to local problems be generated within the context of their overall effect on the system.

3.6. Layer 6: Centralize

Centralized applications will be developed to help executives and upper-level managers understand the effectiveness of people, equipment and strategies deployed across the railroad enterprise. This will result in better knowledge of system impacts due to local decisions. It will also provide improved training opportunities with knowledge of actual and real-time yard performance.

3.7. Layer 7: Measure and Report

With the flow of real-time data and the integration into railroad business processes, it will be possible to construct dynamic yard efficiency, productivity, safety and operational performance metrics to augment the static measures of today. Data mining techniques will be utilized to create rich, analytical reports from the flow of real-time data. Key Performance Indicator (KPI) dashboards will provide a real-time view into the rail world.

4. LAYER 1: CONTROL

Every railroader understands the advantage of replacing a manually operated switch, derail, or any flagging or blocking device with a powered equivalent. It is obvious a railroad will run more efficiently and safely when manual operation is replaced with automated remote control. However the cost of acquiring, installing and maintaining power equipment must be considered and a Return on Invested Capital (ROIC) estimate must be made on a case by case basis. Whereas tremendous returns may be derived by replacing manual switches with powered switches in large classification yards, it would be difficult to justify that replacing a single switch on a seldom used industrial spur will produce any amount of return over any reasonable time frame.

To achieve full automation of manual devices, there must be a technology migration path defined to create value at each step along the path. The Integrated Rail Yard Automation (IA) framework provides this path.

Whereas a reasonable ROIC can be achieved by applying remote controlled switch/derail technology at targeted locations, the number of qualified locations will expand when multiple methods of remote control functionality are added to the mix through integration. For instance, in addition to adding remote control capability to a few heavy use switch locations, it is also possible to coordinate a number of powered switches on a switch lead to line specific routes when commanded.

Alternative methods of control are required to match the current operational characteristics of certain yard locations. For instance, some yard operations require a controller positioned in a tower to command train movement within the yard. Tower operators will generally work from a hard-wired control panel, or from a PC-based workstation to actuate remote control of field equipment. The panel/workstation will graphically depict the yard layout of tracks, switches, derails and flagging devices, and will display train location through track circuit detection means.

Other yard operations may not have tower operators available, so other remote control methods must be accommodated. Some prefer the crew on the ground actuate the power devices. This can be accomplished through either handheld devices or through local control panels strategically located throughout the yard. Typically the switch crew already carries handheld voice radios, and when the radio is equipped with a keypad, this can be effectively used to throw switches and even line routes. The local control panel method is very similar to the control panel in the tower, except they are hardened for the outdoor environment, and they can operate in a network of similar control panels, each controlling certain locations in the yard.

As railroads begin to deploy the first few layers of the IA framework, some of the separate systems deployed today will begin to merge into the IA umbrella. For instance, though the hump process control system is a stand-alone application, some information contained within the hump system will be extracted for use in IA, such as car switch lists and classification track lineups.

Also, trains/engines under RCL control will be considered part of the tracked and protected TECC resource. It is likely some control aspects described in the IA framework will merge into the RCL's operator control unit and it is possible engine speed control commands will be generated and communicated by the Command, Control, Communication and Information (C3i) platform. This means the C3i will have knowledge of active RCL operations within the yard and will be able to associate specific crewmembers with RCL jobs and with protected track locations. This sets the stage to communicate train presence warnings directly to crew that may be in harm's way.

5. LAYER 2: PROTECT

Automation is an opportunity to greatly improve safety conditions for crew members and equipment. Though sometimes considered an intangible benefit, improved safety in these dangerous operations will become a major component in the ROIC calculation.

When automation is adopted, new operating paradigms emerge. The transportation department will have remote control capability of switches and routes that are also controlled by the car department. The engine department will need to occupy tracks controlled by both transportation and car departments. Coordination between these crafts must be addressed. An operating platform must be deployed to provide the requisite coordination between these groups. The mission critical C3i platform will essentially become the traffic cop for all TECC resource movement. The multi-functional platform will provide all automation functions, safety assurance, data communication routing, coordination among all modes of control, data logging, and event playback.

For example, the C3i platform will assure that when a route is commanded, it will first verify the requested route will not violate any pre-existing safety protection. If the car department previously blocked a certain track in the requested route, the route will not be allowed. The C3i system will then present alternative routes which do not violate any previous track or switch blocks, or current track occupancies. Similarly, if a crewmember from the car department requests a track protection that is already locked in a route, the protection will be denied by the C3i system.

The C3i platform will be capable of keeping track of all possible routes within even the most complicated yard track layout. It will be capable of blocking tracks by lining and locking switches away from blocked tracks. It will also know when there is a route that must be protected by derail, where lining a switch away from the requested "block track" will not provide adequate protection.

With the advent of personal train awareness alarm devices, crewmembers can place track protections on blocked tracks, and receive a direct alarm if the protection is violated. With C3i awareness of crew assignments and real-time operating conditions within the yard, it is now feasible to communicate directly to individual crewmembers that may be placed in harm's way.

6. LAYER 3: TRACK TECC

As automation expands throughout the yard, additional opportunities for improved safety will emerge. The next layer within the IA framework provides active and real-time tracking of all mobile assets, including Trains, Engines, Cars and Crewmembers (TECC). By deploying the Track TECC layer, a number of additional CONTROL and PROTECT applications will also be enabled.

One application involves detecting and enforcing the blind movement (shove move) of cars. In an RCL controlled train, the engine is equipped to provide location and speed information to the on-board Locomotive Control Unit (LCU). This information is used by the LCU to enforce pre-determined speed limit rules and to protect certain locations from which the engine is restricted. With this system the operator on the ground is prevented from performing unsafe train movement in the forward direction, i.e. locomotive in front pulling cars in the rear. However, there is no such protection when the engine pushes (or shoves) the cars. In this operation, the cars are leading the train, and the RCL operator may not be in position to view the first car at the end of the train. There is nothing preventing the RCL operator from shoving the cars into compromising or even dangerous locations, such as through an unprotected grade level crossing.

When Layer 1 (Control) is deployed, a necessary component will be a car detection system to prevent remotely controlled power switches from throwing under and derailing cars. When properly selected, the car detection equipment can be deployed in such a way to protect inadvertent switch movement and to effectively track all cars within the equipped locations.

By deploying the car tracking/switch protection network, multiple applications emerge, including:

- Identify and track Trains/Engines/Cars/Crew in real time as they switch throughout the yard
- Communicate warnings to crewmembers when they enter protected zones
- Highlight and measure dwell time for each individual car including any hazardous cars
- Protect TECC from inadvertent collisions and hazards by defining and enforcing protection zones
- Automate car flagging for maintenance
- Measure switching productivity and accuracy
- Provide distance to couple measurements to ensure proper coupling speeds
- Detect and prevent cars from obstructing adjacent tracks
- Automatic and real-time car derailment detection
- Produce alarms if an asset triggers a pre-determined handling threshold.
    - For instance, if a freight car with perishables is not processed in time; or
    - A previously lost freight car appears in the system; or
    - A car or engine is due for maintenance; or
    - A crew member exceeds hours of service law

7. LAYER 4: COORDINATE

Prior to deploying an IA infrastructure, cooperation and coordination between multiple railroad departments is based on verbal instruction and manual operation. The transportation department wants to bring a train into the receiving yard, but a track needs to be manually lined before the train can enter the yard. An outbound train is ready to depart; it only needs engines from the locomotive department. The locomotives were already delivered, but perhaps to the wrong train. The transportation department is ready to hump the next train, but needs to coordinate with the car department to complete car inspections. The car inspectors are already busy inspecting another train, even though this may be a lower priority train. It goes on and on, and the attempt to coordinate these complex conditions can drive a contentious wedge between departments.

One of the key benefits to a coordinated IA strategy is the ability to safely share switches, derails, and blue flags between multiple crafts. Shared route control between car, engine and operations departments and the ability to provide protection by lining tracks away from a controlled, blocked track provides direct operational benefit to all departments.

The coordination layer provides an opportunity to create new business processes for the operating railroad to best manage its “connected” assets. With Wi-Fi data communication networks largely in place, it will now be possible to update crewmembers with electronic work instructions. Electronic instructions are approved by the yard manager and replace today’s paper-based work order system. The manager will now have the ability to immediately re-direct crews to the highest priority tasks, improving overall yard coordination and efficiency. Not only will the manager be able to automatically re-assign a crew a new task, but the integrated system will also line and lock an available route to efficiently move the TECC resources to the new task.

In the Remote Control Locomotive environment, the RCL operator will receive task instructions through the Operator Control Unit (OCU) display. The RCL operator will have immediate access to all the existing locomotive control features plus the ability to control an individual switch, line a route, start/stop/pause a stacked route switching process (see Layer 5: Optimize), receive distance to couple information, shove track indications and work instructions. The RCL operation will be coordinated with movement of other mobile assets in the yard, creating the basis for an optimized, real-time operating plan.

8. LAYER 5: OPTIMIZE

Off-line strategic planning tools are being utilized to model, simulate and optimize many operating scenarios including enterprise blocking plans, train schedules, locomotive utilization and train meet-pass strategies. In this 5th application layer, real-time data will be presented to some of these planners, and the planner will converge on rapid solutions to optimize actual operating conditions. The interface of real-time data to the proven strategic planner will provide a tactical decision making tool.

Optimization today is primarily a result of the application of strategic planners that simulate certain historical operating parameters. As an example, capacity planning, train scheduling, and crew scheduling (among others) simulators are used to study the overall system effects due to planned changes in track configuration, traffic, and multiple other possible scenarios.

The proposition in deploying the seven layer IA architecture is to convert the off-line, strategic planners into real-time, tactical planners. The tactical planner will provide rapid analysis of the effect of exceptions to the strategic plan. As any railroader knows, exceptions to the plan are common.

Decisions made to address any exception are best handled by an experienced employee. But no matter how experienced the employee, the decision will be made based on the local yard conditions with little to no regard to trickle-down effects to the system. With real-time tactical analysis it will be possible to completely evaluate upstream and downstream system effects due to any local decisions.

Through connected devices, real-time data can now be made available to the tactical planner. Due to the Wi-Fi networks, new instructions can immediately be broadcast to crews in the field. It is now possible to dynamically assign tasks to modify work orders, and immediately shift crews to high priority tasks that may be driven by exception events.

Since application layers are connected, one can envision all systems working in concert. As an example, assume a car inspector detects a mechanical defect in a car coupled to a high priority train preparing to depart. The employee will communicate through a PDA application the car information and location, and indicate the defect will prevent the train from departing on time. The exception will be immediately received by the tactical planner, and the planner will generate the corrective action required to minimize network-wide impacts on this potential delay. The tactical planner’s highest recommendation is to immediately route a crew to uncouple the defective car. The yard master receives the recommendation on his connected PDA, and accepts the advice. By clicking accept, a series of events are launched. First, the closest crew with the lowest priority activity will receive a priority update to their current work plan. When the crew accepts the update, a route from the crew to the defective car will automatically actuate, line and lock. There were track protections already in place prior to the route forming, so the route forms around the protections, keeping other crews protected and safe. While this activity is occurring, the car inspector continues to inspect the soon-to-be outbound train. Once the switch crew arrives at the track, the inspector releases protection from his PDA, and the crew can now switch out the defective car.

The capability to provide coordinated information flow, situational analysis, and direct command of the situation is only a matter of time. All of the individual elements required to support this 5th level of automation exist in production equipment currently deployed in the railroad environment today. What still needs to be done is to connect data generated from each disparate system, and the eventual widespread deployment of the basic components to be connected.

Tactical planners assist management in making real-time recommendations to optimize and balance yard operations. The type of solutions the tactical optimizer can recommend includes:

- The selection of optimal track location for all inbound trains.
- Work order communicated to car department to perform pre-hump inspection
- Selects the optimal cut to hump based on multiple selection factors
- Provides dynamic classification track designation based on optimal block grouping
- Work orders communicated to trim tower to begin outbound train assembly
- Work order communicated to car department to perform outbound train inspection and brake test
- Communicates estimated time of departure to mainline dispatchers

9. LAYER 6: CENTRALIZE

Now that we are connected, the natural location to accumulate the thousands, if not millions, of data messages will be a centralized data center. For most large railroads the data centers already exist. By centralizing the data, it will be possible to interface the real-time information with other operational and administrative applications. It will also be possible to provide a real-time view of “yard readiness” information for mainline planning and control systems.

Centralized applications will be developed to help executives and upper-level managers understand the effectiveness of people, equipment and strategies deployed across their railroad enterprise. This will result in better knowledge of system impacts due to local decisions and will provide improved training opportunities with knowledge of the measured yard operations.

Enterprise tools will be created to ensure car sorting operations are working at capacity and meeting corporate goals and schedule requirements.

Communication of all yard-derived data back to central database servers for real-time analysis and data mining operations will create an accurate picture of equipped yard performance. Critical issues can be quickly assessed, and high priority work orders can be generated from central or local management. Work orders will be based on running real-time simulations to assess potential impact with regard to system relationships. This will allow centralized, tactical planning with intelligence through actual data generated from all yards, and eventually from mainline operations as well.

10. LAYER 7: MEASURE AND REPORT

A process to analyze data from different perspectives and summarize it into useful information will be accomplished through expert data mining tools. This will allow users to analyze data from many different dimensions, categorize the data, and summarize the relationships identified. Rich and meaningful reports will be derived from the volume of data generated and collected at the central database location. Some of the parameters that can be tracked and measured include:

- Track performance metrics of each crew
- Response time to high priority work orders
- Number of work orders completed per shift
- Number of cars handled per shift
- Accumulated Time at current location
- Accumulated Time at all locations
- Number of times each car has been switched

- Average/Actual number of cars on receiving, classification, and departure yards
- Average/Actual dwell time spent by cars on receiving, classification, and departure yards
- Average terminal dwell time for the cars
- Number of cars humped/switched per crew
- Number of cars re-humped
- Number of cars inspected
- Optimize car placement within train

Operating and performance targets will be set as Key Performance Indicators by central management and actual performance will be measured against the target figures. The KPI Dashboard will provide a real-time view into all key yard operation metrics, through constant monitoring and real-time reporting from each equipped yard.

11. RECOMMENDATIONS

Much of the seven layer IA architecture exists today, albeit in a stand-alone form with each application operating independently. Through careful selection of a mission-critical C3i platform, it will be possible to connect these stand alone applications and derive significant benefit through coordinated tactical planning and centralized communication of key performance indicator metrics.

The task of building the layered applications will best be accomplished with a railroad operator and a systems integrator working in partnership. The system integrator must have an understanding of railroad operations as well as expert knowledge of the various hardware components and systems that must be included. The system integrator should be able to provide the railroad with a list of qualified and appropriate equipment to be used in each layered application. Remember, the intent is to connect through data communications all equipped devices. If one selects a hardware component that does not lend itself to connectivity, then this equipment will need to be replaced. This is obviously an expensive proposition, so choose an integrator that understands all elements of the architecture, and has no vested interest in the recommended hardware.

Finally, be cognizant of the next generation mainline train control technologies currently being planned including ERTMS in Europe, ATACS in Japan and PTC in the US. These mainline initiatives hold promise for not only safer mainline operations but also closer headways, higher velocities, and even more data! It is time to begin building the railroad infrastructure now, one yard at a time, to become compatible with a modern and efficient mainline. It will be of little value to spend billions of dollars improving mainline efficiencies if all is lost in the manual operations found in most yards today.

Legend of Abbreviations

- Train-Engine-Car-Crew (TECC)
- THE HUMP AND RCL (Remote Control Locomotive) Automation of the rail yard
- PDA devices- (Personal Digital Assistant)
- Integrated Automation (IA)
- Return on Invested Capital (ROIC)
- Operator Control Unit (OCU)
- Locomotive Control Unit (LCU)
- Command, Control, Communication and Information (C3i) platform
- Operator Control Unit (OCU) display
- KPI Dashboard- Key Performance Indicators
- ERTMS in Europe- European Rail Traffic Management System
- ATACS in Japan- Advanced Train Administration and Communications System
- PTC in the US- Positive Train Control

Reference List

1. G. Gormick, "How fluid is your yard?", Railway Age, August 2005, p18-28.

2. Federal Railroad Administration, Yard and Terminal Safety, October 30, 2008.