ROCC AND ROLE: IMPLEMENTATION OF RAIL OPERATIONAL CONTROL CENTRES FOR RESILIENCE

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SUMMARY

Resilience is the ability to recover quickly from situations that don't go to plan. Railways are a complex and complicated business. Customers demand improved performance and value-for-money whilst rail operators strive for business excellence but often struggle for fiscal prudency.

Running a railway to plan without incident, achieving customer satisfaction and business success are major goals for rail operators. An effective Rail Operations Control Centre (ROCC) is the 'heart and mind' of rail operations that can meet those goals. This paper examines the role of the ROCC in contributing to the resiliency of rail operations.

1 INTRODUCTION

Resilience is the ability to cope with difficulties and situations that don't go to plan. Being resilient is being able to recover from those difficulties, getting back to plan and often being stronger than before. Resilience is not just about surviving but having the mechanisms, latitude and flexibility to actively return to normal conditions.

Running trains to schedule day in and day out without incident, according to the timetable and being consistent is a major challenge. Any number of incidents from equipment failure, to passenger issues, to external events such as bad weather, can cause the railway operations to deviate from the plan. The challenge is how best to manage those situations in the safest and most effective manner to maintain the desired operational state.

This paper describes how a Rail Operations Control Centres (ROCC) can contribute to rail operational resilience and provides a framework for the planning and development of a ROCC to achieve such resilience, customer satisfaction and business success.

This paper introduces rail operations describing operational modes and defining operational resilience. It then characterises a ROCC and establishes the resilience framework.

2 RAILWAY OPERATIONS

2.1 Rail Operations Organisation

Rail operations involve providing a transportation service to customers to achieve requirements such as safety, punctuality, availability, capacity, efficiency, and cost-effectiveness. IEC 62290 Railway applications – Urban guided transport management and command/control systems [1] considers operations "as the totality of all means to effect the transportation of passengers" and for train operations as "command and control of routes, passenger transfer, driving of trains and also shunting". Railway operations apply to both passenger and freight services. For freight services goods are carried rather than passengers.

IEC 62290 [1] also considers the organisation of railway operations structured generally into the following tasks:

- Planning operation (including timetable, train and staff resources);
- Operations management and supervision (Operations Control Centre);
- Execution of train operations;
- Detection and management of emergency situations;
- Maintenance for all facilities and equipment of the transport system, especially infrastructure, and trains.

The organisation of rail operations from IEC 62290 [1] is shown diagrammatically in Figure 1.

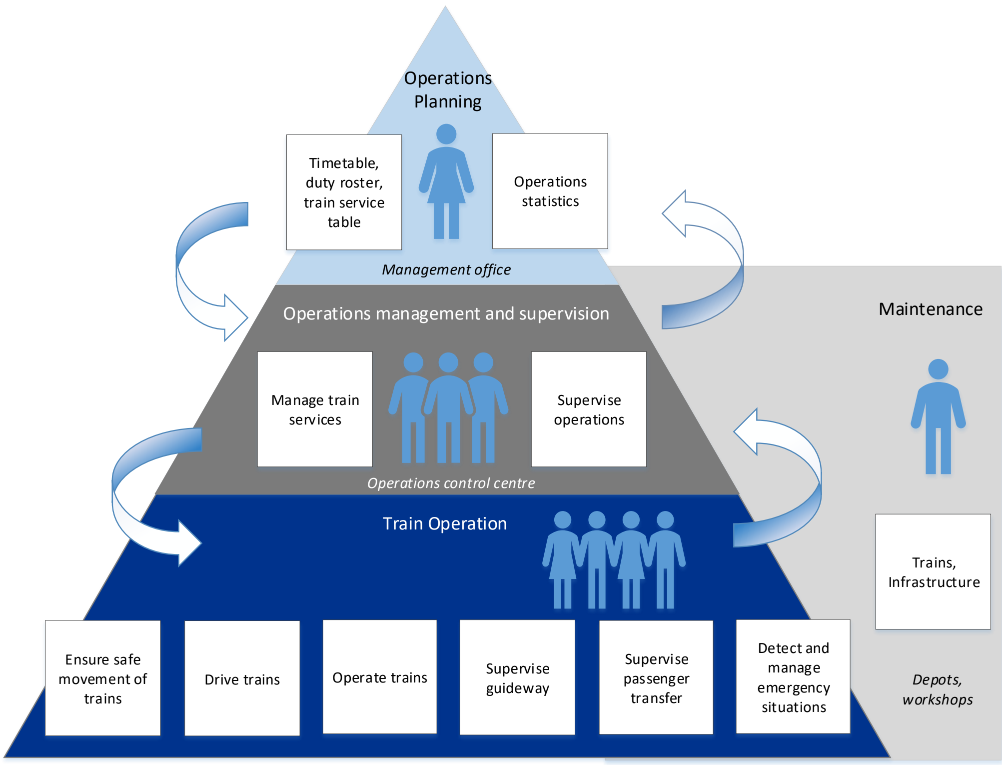

Figure 1: Organisation of Rail Operations

2.2 Rail Operational Modes

Rail operations can be classified in terms of the mode of operations as follows:

- Normal mode. This is when the railway operates as intended according to the operations plan, including planned peak periods and all relevant equipment and infrastructure operating correctly as designed with no incident. This includes the management of non-service affecting incidents or temporary overload / perturbations that may result in delays but are recoverable in the short-term (abnormal operations);
- Degraded mode. This is when the railway operates in a restricted manner for a period of time due to an incident that impacts the service delivery (service affecting incident);
- Emergency mode. This is when there is an incident that has serious service disruption, life-threatening or extreme loss implications that requires immediate attention (e.g. a fire on the train). This would be a service affecting / major incident.

Incidents are unplanned or uncontrolled events that may impact the normal mode of operations as follows:

- Technical incidents. Railway infrastructure, systems and equipment failures where the function cannot be performed (e.g. signalling failures, rolling-stock failures, broken rails, software faults, etc);
- Customer incidents. Impacts caused by the customer (e.g. passenger causing a train to be stopped at a station longer than usual, unauthorised entry onto the running line, activation of emergency stop plunger etc);
- Operator incidents. Impacts caused by the rail operator or maintainer themselves (e.g. crew not available to operate the train service, maintenance work runs into operational hours, signals passed at danger, etc);
- External incidents. Other external factors that impact the rail operations and often where the rail operator may have little influence to control but can only manage the situation (e.g. extreme weather events, flood / fire, security threats, livestock crossing the railway line unauthorised etc).

Normal mode can be restored once the incident is cleared. The degree of transition to degraded or emergency mode depends on the service-affecting nature of the incident as follows:

- Service affecting. Incidents that impact the service delivery (the running of trains) resulting in degraded or emergency mode of operation. Major safety incidents are considered as service affecting (e.g. rolling stock failure on the mainline, fire, flood, etc);
- Non-service affecting. Incidents that do not immediately impact the service delivery and where the service can be maintained (e.g. passenger illness on a station, failure of one train door, failure of a primary computer server but operating from the back-up). However, if not responded to in a suitable manner may become service affecting resulting in degraded mode (e.g. operation on back-up server but primary server remains down).

2.3 Rail Operational Resilience

Operational resilience considers the ability of the rail operations to adapt, to respond, and to mitigate incidents especially those that are considered service affecting and thereby by their nature may be unsafe, hazardous or compromising (e.g. continued delay and break-down may lead customers to seek alternative transportation means).

The normal mode of operation is the desired state of the railway. Figure 2 shows a state transition diagram for railway operations from start of service (t_{start}) to end of service (t_{end}) for a given day. Transitions to abnormal (t_a), degraded (t_d) and emergency (t_e) modes of operation are shown.

Being able to maintain normal operations despite incidents is being resilient. If there is an incident, rail operations endeavour to respond to the incident in a safe manner within a defined period to restore the service back to normal mode.

Referring to Figure 2, the rail operation resilience improves when $t_n \longrightarrow t_{doo}$ (i.e. when $t_n >> (t_a + t_d + t_e)$ as $(t_a + t_d + t_e) \longrightarrow 0$). In other words, the lesser of time required to respond to an incident to restore normal operations, the more resilient the rail operations becomes. Rail operators use all manner of its personnel, facilities, rules and procedures at its disposal to successfully deal with the incident and recover the operations.

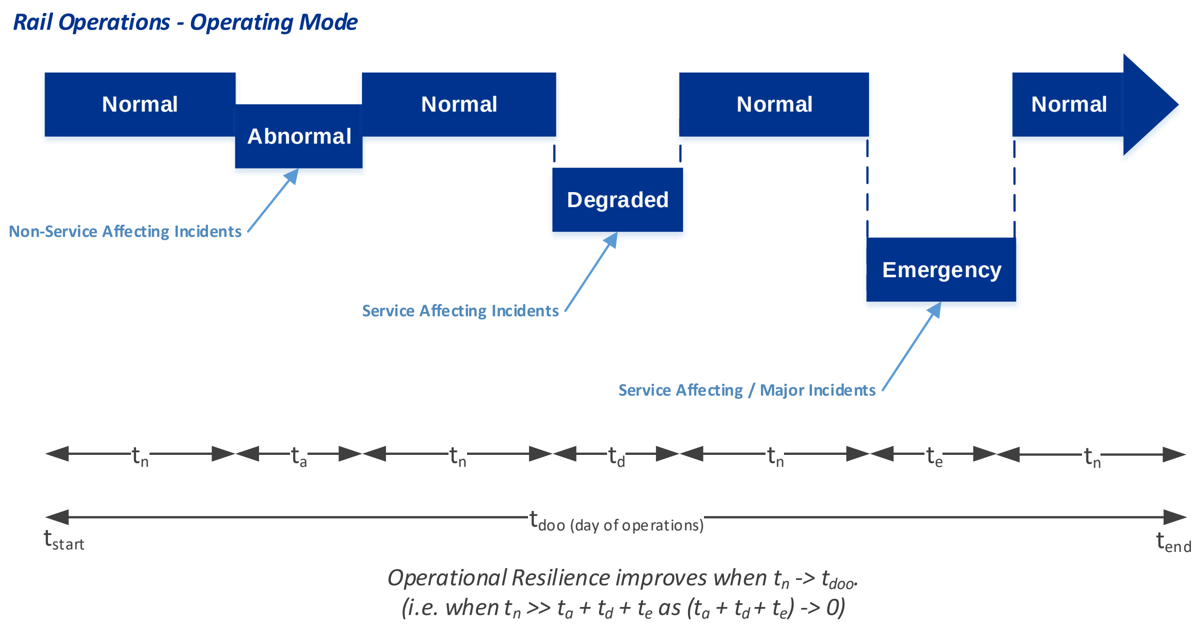

Figure 2: Rail Operations Resilience Model

3 RAIL OPERATIONS CONTROL CENTRE (ROCC)

3.1 Overview

The ROCC is a facility of people, processes and technology to deliver the operations plan. It is generally the primary command and control hub to manage rail operations.

The ROCC is typically concentrated in a few locations, in some cases only one. It usually occupies a dedicated building (or floors / rooms within a building) and contains a main control room for the day-of-operations control purposes. The ROCC is often considered a ‘show-piece’ for the railway operator.

Currently, it is not common for railway operators to concentrate the functions of the ROCC into one facility. Support and other functions are typically performed at headquarters or other administrative facilities. A modern ROCC is shown in Figure 3.

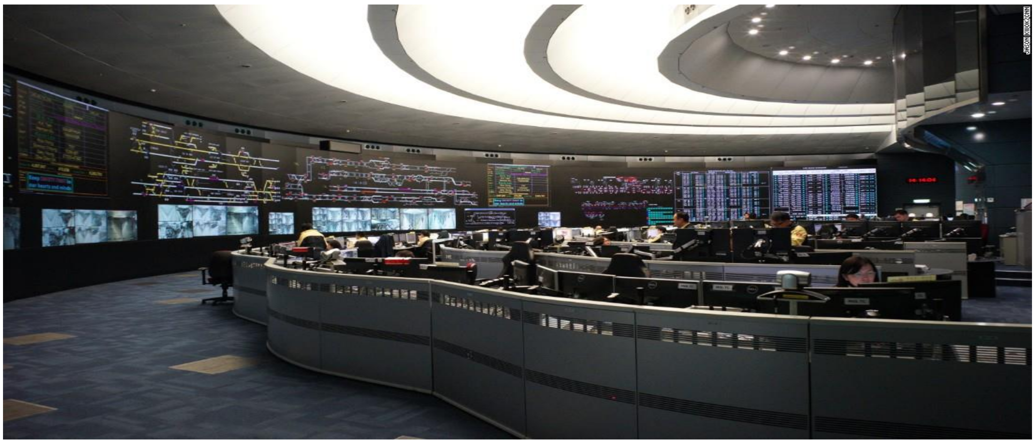

Figure 3: Modern Rail Operations Control Centre

3.2 ROCC Benefits For Operational Resilience

The ability of the railway to be resilient and to continue to provide a suitable service in the face of incidents requires rail operations to have ‘situational awareness’ at all times. This ability to be highly aware is the real act of resilience. This is where the ROCC can contribute to rail operations by always knowing the current state of the railway, having the ‘situational awareness’ and if an incident arises, the ROCC can respond to the incident in a manner that minimises (ideally, eliminates) the disruption to service.

The benefits of the ROCC contributing to rail operation resilience can be summarised as follows:

- Safety benefit;
  - Improved supervision and situational awareness of the railway.
  - Improved risk management including the use of engineering controls compared to administrative controls.
  - Improved incident management and response.
- Performance benefit;
  - Achievement of Key Performance Indicators (KPIs) including on time running, throughput, and customer satisfaction.
  - Improved information, communications and decision-making to manage operational variability.
  - Reduction of frictional losses between interfaces.
- Operating benefit;
  - Improved work-flows, processes and sharing information to manage the complexity.
  - Optimised staffing levels, flexibility and adaptability.
  - Potential to reduce operating costs.

4 ROCC FOR RESILIENCE – OBJECTIVES

4.1 Overview

A set of principles (framework) for establishing, planning and developing a successful ROCC to achieve resilient railway operations are:

1. Stating the operating objectives and key ROCC organisation and functions (refer sections 4.2 and 4.3);
2. Determining the ROCC operational integration requirements (refer section 5);
3. Deciding upon the desired systems integration approach (refer section 6).

4.2 Operating Objectives

For the ROCC benefits to be realised, the operating objectives of the railway for which the ROCC is to contribute must be defined. The railway operating objectives are typically described in a Concept of Operations document and a resultant Rail Operations Plan. Whilst safety and availability objectives are a given, objectives for different type of railway operations based on performance criteria can be:

- For a metro / passenger operations;
    - Capacity (passenger throughput - number of passengers per hour per direction).
    - Service frequency and run-times.
    - Punctuality, availability and reliability.
- For heavy haul / freight operations;
    - Capacity (mega tonnes per annum / net tonnes per kilometre).
    - Load / consignment tracking and on-time delivery.
    - Other service delivery performance (e.g. loading / unloading times, driver 'footplate' time, target cost of haulage per tonne).

The operating objectives establish the foundation for the ROCC organisation and its functions.

4.3 ROCC Organisation and Functions

Based on the railway operating objectives and desired operations plan, the organisation and functions of the ROCC can be established. A typical model for the ROCC organisation and its associated functions aligned to rail operations are:

- Planning and scheduling;
    - Capacity analysis, demand forecasting, service design, and scheduling of train services.
    - Workforce planning and rostering of staff.
    - Resource, assets and maintenance planning.
- Day of operations;
    - Advisory, supervision and operational safety management.
    - Steady state operation (normal live run / execution of train services (dispatching, controlling and monitoring) according to safe-working procedures and schedule.
    - Regular transient operation (such as start-up and shut-down of the service delivery).
    - Minor variation management.
    - Management of work sites, provisioning, and maintenance facilitation (scheduled or unscheduled) on the running railway.
- Incident management;
    - Incident and emergency situation response.
    - Incident investigation.

- Support / Other;
  - Regulatory compliance.
  - Work health safety and environment management.
  - Staff competency, training and development.
  - Financial, administrative, and procurement management.
  - Maintenance and asset management.

5 ROCC FOR RESILIENCE - OPERATIONAL INTEGRATION

Specifying the ROCC is a very challenging task with many variables to consider. To define the ROCC organisation and function, and ultimately to implement the ROCC, a framework to characterise the ROCC can be based on a set of operational integration criteria as follows:

- Time Horizon – time coverage of the ROCC for the service provision.
- Hierarchy of Control – the coordination strategy the ROCC needs to provide.
- Geographic coverage – the geographical area of the ROCC needs to cover.
- Asset coverage – the assets included by the ROCC.
- Functional coverage – the functionality provided by the ROCC.
- Operating coverage – the operating locations and degree of centralisation of the ROCC.

The ROCC operational integration model is shown in Figure 4.

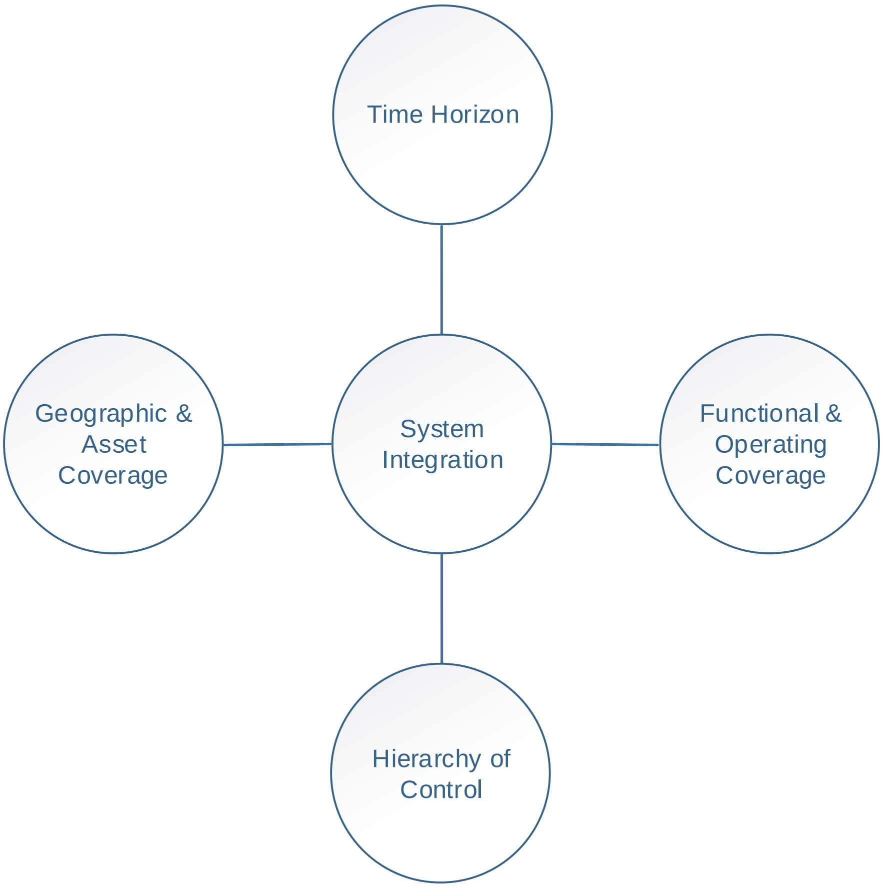

Figure 4: ROCC Operational Integration Model

The ROCC operational integration criteria are further described in sections 5.1 to 5.6.

5.1 Time Horizon

The time horizon is the length of time coverage for the provision of the railway operational service by the ROCC. The time horizon is the duration of an intended operational service from start to end. Note this is not the design life of the ROCC but the time span of the operating functions provided by the ROCC.

The time horizon for the railway operations can be measured in terms of planning, scheduling, day of operations and incident response as follows:

- Planning. This includes strategic planning, service design and operational improvement. Its time span is generally from three (3) months to two (2) years. It also includes planning for maintenance shut-downs of the railway as necessary and major revisions to the timetable. Planning is important to ensure that resource requirements are appropriately allocated and available for future operational needs. Planning also includes allowing for prospective changes to the network configuration and other assets. Preparing for future activities means risks can be identified and mitigated providing a 'built in' resilience to the planned operations.
- Scheduling. This involves the provision of operations and maintenance resources (e.g. trains, personnel, materials) and includes modification of the timetable to provide the near-term service delivery. Its time span is generally from one (1) day to three (3) months before day of operations. Service needs can be identified and included for the expected demand and thereby deliver a resilient operation.
- Day of operations. This is the live execution of the service delivery to provide the normal operations including managing minor variations and perturbations. This is generally a daily, twenty-four (24) hour less maintenance downtime operation. The ROCC should provide the people, processes and technology to allow an effective service and the ability to manage variations as part of the day-to-day operational resilience.
- Incident management. This is the management of degraded or emergency modes during the day of operations execution and is measured in hours / minutes. Incidents are impacts to the service delivery that must be effectively managed by the ROCC. The ROCC must provide the features and functions to manage incidents, minimise their impact and return to the normal mode in an effective manner. The ability of the ROCC to manage incidents, especially those that are service affecting, is a significant contribution to rail operational resilience.

Figure 5 shows an example of the time horizon of railway operations. Planning and scheduling is usually performed by information technology and business systems whereas day of operations and incident response is typically managed by real-time operational technology systems.

In many railways, it is not common for the ROCC to include the planning and scheduling functions. These are usually performed in administrative offices. However, the close coupling of the time horizon activities at the ROCC should allow for an integrated and optimised operation due to improved communications and coordination of the personnel and their activities.

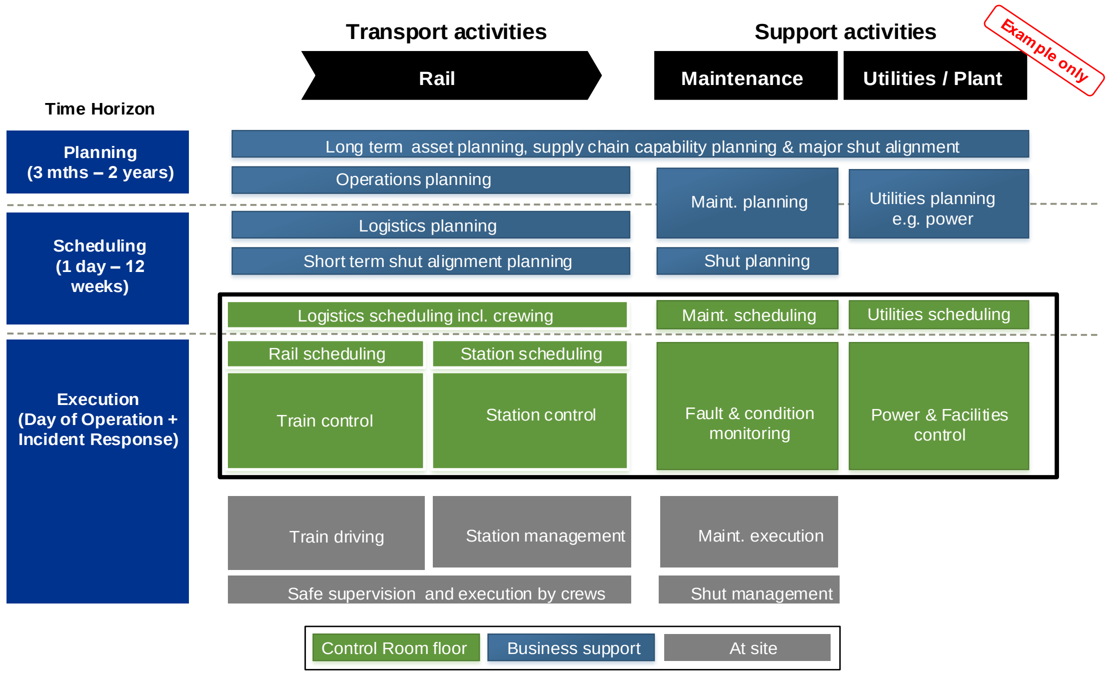

Figure 5: Time Horizon Example

For any prospective railway operation and planned ROCC development, the time horizon of the ROCC should be specified.

5.2 Hierarchy of Control

The hierarchy of control is a coordination strategy to manage the rail operations. It is commonly based on a top-down 'chain of command' approach for the authority of operations. It considers the complexity, responsibility, and reaction times of the authority.

The hierarchy of control identifies the primary control that is the control level with the wide-ranging authority, the fastest response times, and is best able to manage the operational dynamics and variables.

Secondary control is the control level with specific or assigned authority for localised situations, often as a fall-back for degraded mode operations or for self-contained operations. Levels above the primary control generally apply for enterprise strategy, management, and supervision functions. Levels below secondary control generally apply at field and equipment levels.

For a metro or conventional railway, the hierarchy of control may be structured as:

- Network;
- Line(s);
- Station(s) / Depots;
- Equipment.

In this case, the ROCC is typically the primary level of control at a network and/or line level (level 1) and secondary control (level 2) is performed at station and depot level. Network control (level 0) may also provide high level advice and supervision.

For a heavy-haul / dedicated freight railway, the hierarchy of control may be structured on an asset-classification basis such as:

- Above Rail;
- Below Rail;
- Depot, Freight Terminal, Loading / Unloading Facility;
- Equipment.

In this case, the ROCC is the primary level of control for ‘above-rail’ and ‘below rail’ (depending on asset owner and partitioning), and the secondary control level is performed at a depot / freight terminal or loading / unloading facility.

Whilst primary control has the authority and is responsible for normal operations, depending on the situation, secondary control may be granted that authority if considered best fit for the operation (e.g. depot operations).

The hierarchy of control also establishes the responsibility apportionment at each level in terms of what functions are available at each level and the associated control and monitoring rights of users (i.e. who gets what and who is control?). An example of the hierarchy of functional control is shown in Figure 6.

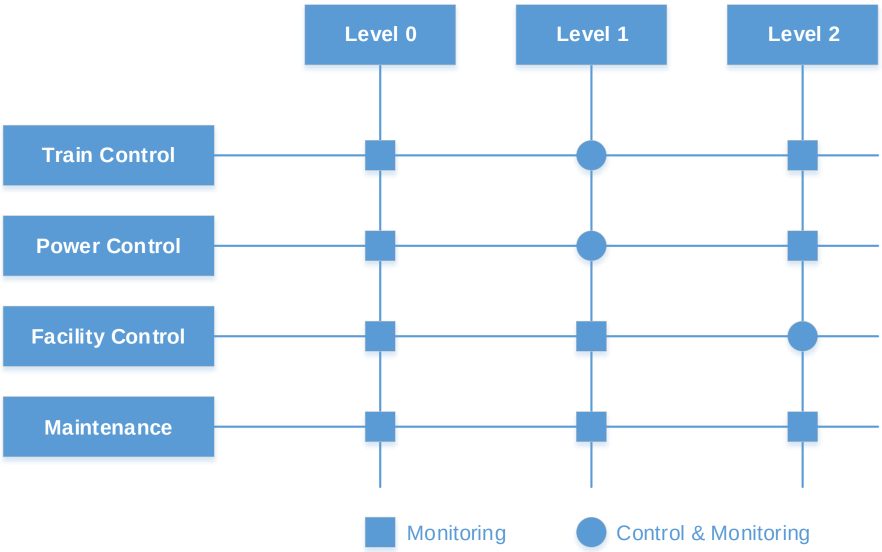

Figure 6: Hierarchy of Control (functional)

Users are typically operations, maintenance, and supervision personnel. Operations personnel generally have control and monitoring rights depending on the control level, maintenance personnel generally have monitoring rights with specialist maintenance control functions, and supervision personnel having monitoring rights is common.

Complex metros or nation-wide railways may more than one ROCC (typically a ROCC per line and/or regional advisory centres). Regardless of the number of ROCCs, the hierarchy of control and the associated authority and responsibilities of each must be determined to facilitate a resilient operation. This is particularly important for confirming the ultimate authority when there are multiple ROCCs.

5.3 Geographical Coverage

A railway operation has a defined geographical area and may comprise of multiple lines. The geographic coverage sets the foundation of the ROCC for its operational scope and resultant asset, functional and operating coverage.

The geographical coverage of the ROCC (or multiple ROCCs) must consider:

- Railway lines (alignment) including mainline, depots, stabling and terminals;
- Geographical territory included international / national, state / territory, region and city areas;
- Boundaries, demarcation and interface points;
- Rail corridor coverage (e.g. fence to fence).

Complex metro railways covering a city may have multiple lines each with its own ROCC. Figure 7 shows a typical metro railway map that could be served by one or more ROCCs. Conventional railways may be nation-wide with international borders served by a few ROCCs. A national freight operator may have its own country wide dedicated railway network served by one ROCC. The geographic coverage of the ROCC must be stated.

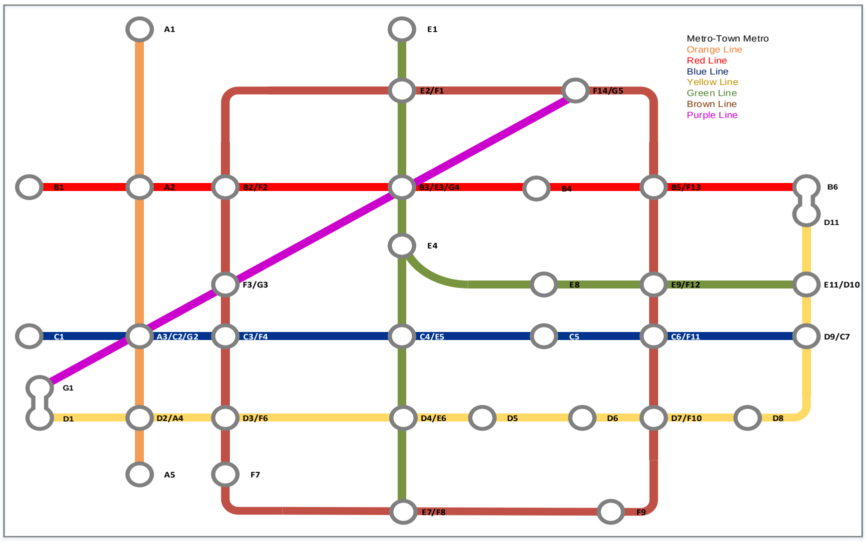

Figure 7: Typical Metro Railway Map

5.4 Asset Coverage

Aligned to the geographic coverage is the asset coverage. The ROCC must consider the assets that will be supervised, monitored, and controlled by the ROCC for its given geographic coverage. The asset coverage may include:

- Network lines and track;
- Civil infrastructure including tunnels, bridges and elevated sections;
- Rolling stock;
- Signalling and Telecommunications;
- Traction Power and electrification;
- Buildings, Stations, Depots, Facilities;
- External interfaces (assets not included).

The decision as to what assets should be included depends on their relative contribution to the service delivery and their impact in case of non-availability or impact on incident management. Generally, the operational resilience is improved with the inclusion of the asset if the asset can enhance the situational awareness. An example of an applicable asset coverage for a ROCC is shown in Figure 8.

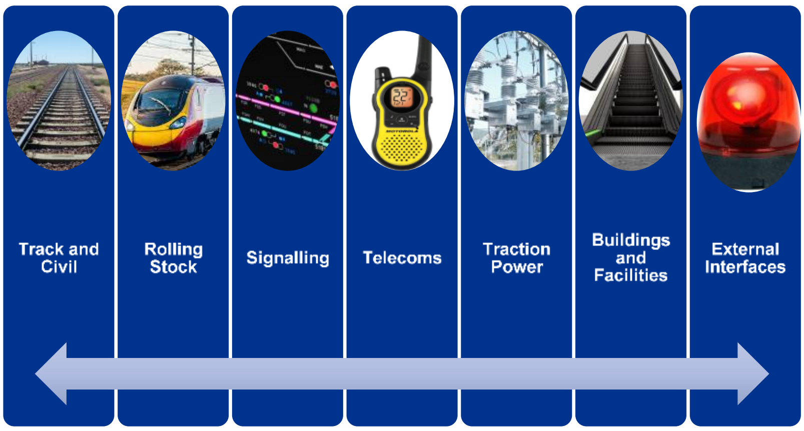

Figure 8: Asset Coverage

The asset coverage of the ROCC must be specified.

5.5 Functional Coverage

Once the asset coverage is stated, the functional attributes provided by those assets in terms of their role that the ROCC performs needs to be assessed and considered (i.e. what assets are monitored and controlled from the ROCC and what functions do they provide?).

The extent of ROCC functional coverage could include:

- Planning and schedule management systems;
    - Planning and schedule management.
    - Rostering, timetables, train graphs, etc.
- Control, monitoring and supervision;
    - Train control and signalling, traffic management (Automatic Train Supervision, train routing, dispatching and tracking). Note that this would be considered one of the main functions of the ROCC.
    - Traction power, high voltage, low voltage, power distribution, and energy management (Power SCADA).
    - Facilities, plant and equipment management (Facilities SCADA) including lifts, escalators, heating ventilation air conditioning (HVAC), environmental control, tunnel ventilation, fire detection, drainage, lighting, platform doors, signage, automatic fare collection.
    - Telecommunications (radio, telephone, passenger information / public address, fixed telecommunications network, WiFi etc).
    - Security and passenger safety (access control, CCTV, intrusion detection, help points).
- Asset condition monitoring and protection (rolling stock monitoring, hot axle box detection, dragging equipment detection, turnouts, civil and track conditions – broken rail, track temperature etc);
- Maintenance and failure detection (diagnostic, equipment health monitoring, alarm and event, historical data);
- Training and simulation;
- Reporting;
- Asset and maintenance management;
- External interfaces (e.g. port, mine, bus, tram, intermodal, emergency services).

The asset and functional coverage form the nucleus of the ROCC to perform its operational capability including the management of incidents. Often these assets are referred to as the operational systems (or operational technology) as distinct to information technology systems. An example of the ROCC functional coverage is shown in Figure 9.

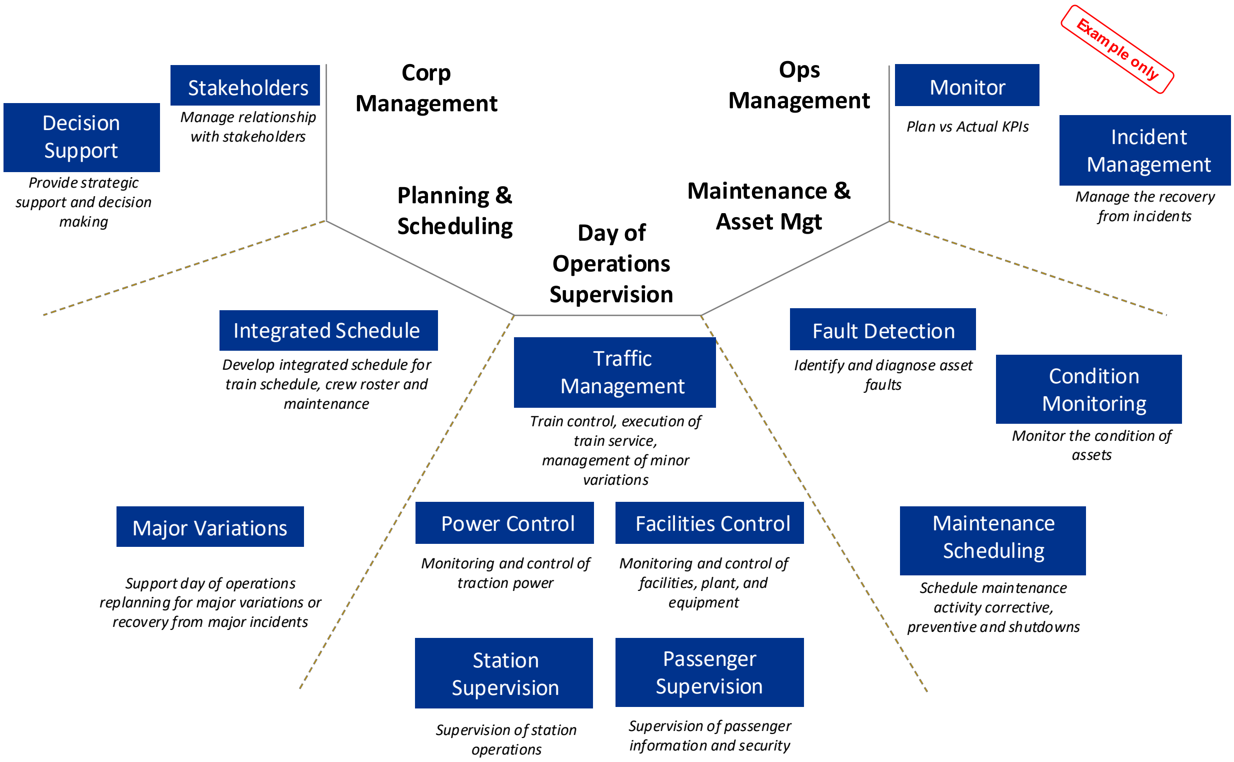

Figure 9: ROCC Functional Coverage Example

5.6 Operating Coverage

The operating coverage refers to the locations where operations are performed and the associated personnel arrangements to staff those locations. A prevailing factor in the operating coverage is the degree of centralised control (i.e. is the ROCC the only point of control and supervision for the railway operations or are there other locations that will perform control or support?).

The degree of centralised operation control is a balance between:

- Fully centralised control versus distributed control;
- Operator control (actuation) versus advisory (supervision).

Figure 10 shows the spectrum of typical ROCC arrangements for various railway operation types considering the degree of centralised and control.

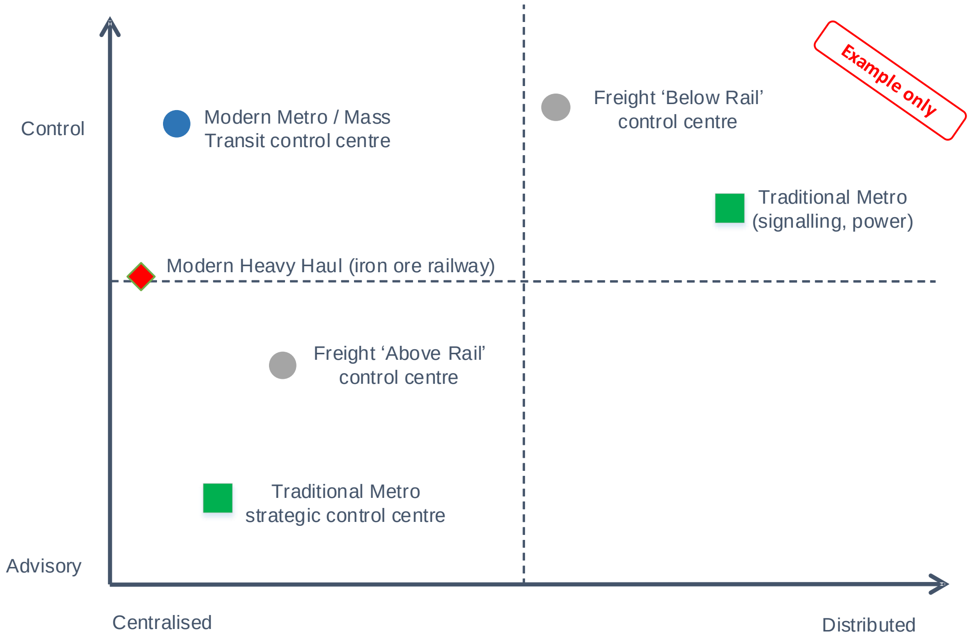

Figure 10: Spectrum of Centralised Control

Fully centralised control constitutes a main central control location (ROCC) communicating with local field facilities to provide the remote control and monitoring and decision-making function. The majority of operations personnel are located at the ROCC. Figure 11 shows a centralised ROCC configuration.

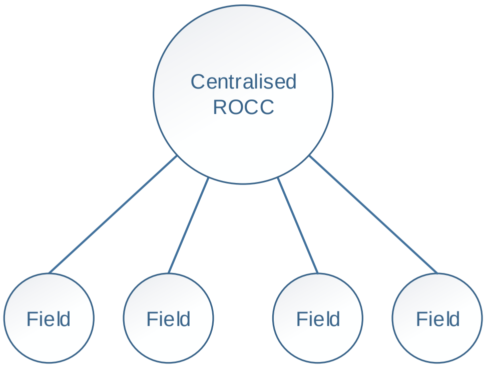

Figure 11: Centralised ROCC

Distributed control can be a traditional model of geographically separate control locations (e.g. separate train control, separate power control) or a regional control based approached where several physical control centres are used to perform a similar task over a wide geographic area (e.g. train control over hundreds of kilometres managed by two or three control centres, traditional signal box arrangements). Figure 12 shows a distributed control configuration.

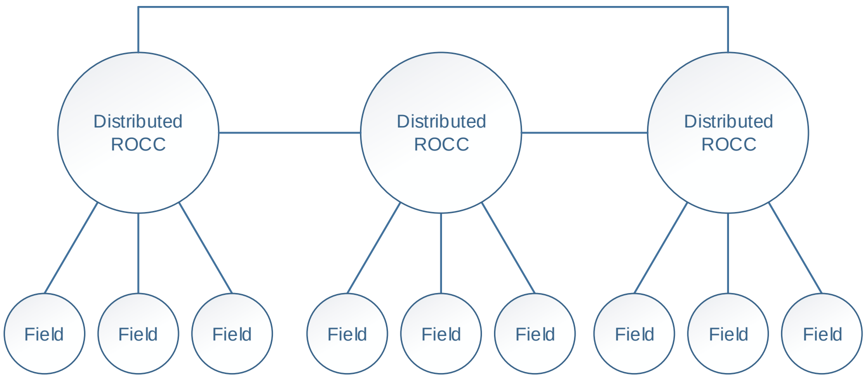

Figure 12: Distributed ROCC

A combined (partially centralised) ROCC is a mixture of centralised and distributed control. It provides global system-wide supervision and control whilst allowing local facilities to be managed. Figure 13 shows a combined control configuration. The combined ROCC configuration allows the provision of supporting control locations as follows:

- Centralised advisory / supervision authority;
- Station control / management system. Each station has its own control room for managing station operations. It may be interconnected to a centralised ROCC;
- Back-up ROCC. This is to provide an alternative control location in case of loss of availability of the ROCC;
- Special purpose and/or standalone control centres. These are control locations used for a special purpose (e.g. depot control, freight terminal control, etc). These may be interconnected to the ROCC.

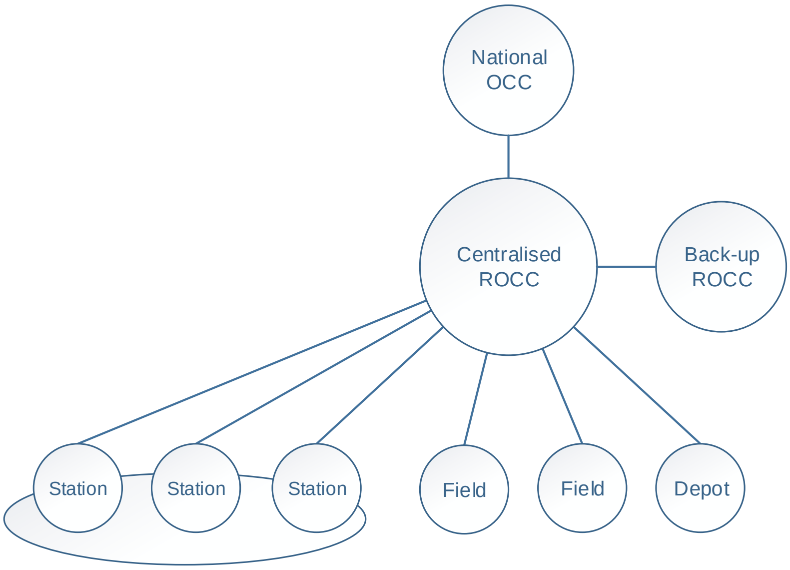

Figure 13: Combined ROCC

Decisions regarding the operating coverage as the best fit for the rail operations organisation should be defined.

6 ROCC FOR RESILIENCE - SYSTEMS INTEGRATION

6.1 Overview

For the ROCC to be effective in delivery of the operations plan and achieve a resilient rail operation, the level of system integration must also be considered. Insufficient integration means there are frictional losses resulting in poor communication and coordination resulting in reduced situational awareness and inadequate reactions. On the other hand, achieving superior integration may be aspirational (i.e. the organisation may not be ready to cope with the change), costly or subject to development risk.

The level of integration drives the implementation and risk mitigation of the ROCC and therefore the appropriate balance must be assessed. The level of ROCC system integration is assessed based on a people, process and technology model.

6.2 People

The 'people' attribute involves defining operations and maintenance personnel roles and responsibilities and associated competency, training and development for the ROCC. It also includes the places of work of job functions. The focus of the ROCC is defining the key operations personnel performing the primary control (e.g. train control, power control, facilities monitoring, passenger communication, and fault handling). The roles and responsibilities map to the operational integration criteria.

6.3 Process

The 'process' attribute involves the policies, plans, procedures and rules for the railway operations. It also includes the level of automation applied to these processes. There is a focus on organisational process maturity and improvement to achieve a consistency of outcome and continued development.

A method to measure organisation process maturity is the use of the Capability Maturity Model Integration (CMMI). CMMI is a training and appraisal program administered by the CMMI Institute [2]. It identifies five (5) levels of maturity as shown in Figure 14.

Many organisations can achieve Level 3 but few attain beyond to Level 5. The CMMI is a useful tool to assess where an organisation currently resides and where it desires to evolve. The use of automation can contribute to the process maturity.

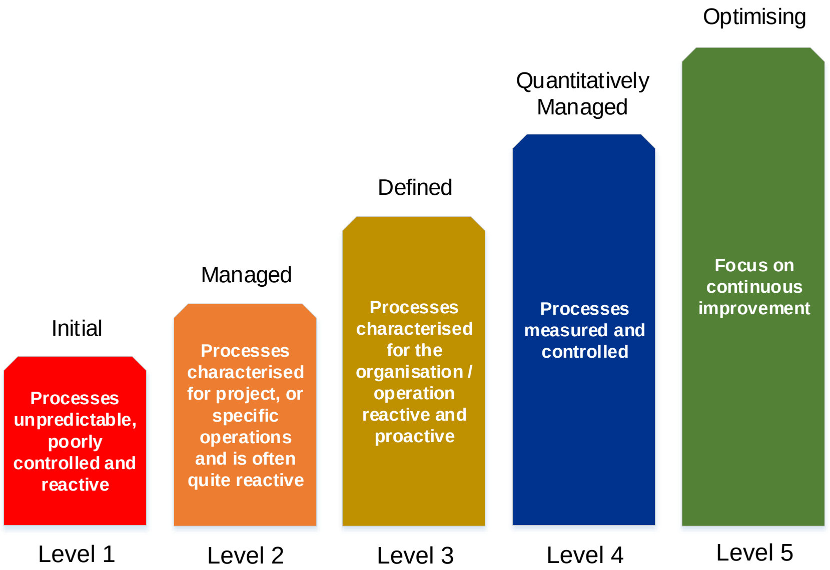

Figure 14: Capability Maturity Model Integration

6.4 Technology

The 'technology' attribute involves level of technical integration including the selection, utilisation and integration of the system assets that provide the functional coverage of the ROCC. The technology may be legacy, commercial-off-the-shelf, or specifically developed technology. For the purposes of the ROCC functional coverage, the technology components are considered in terms of:

- Human Machine Interface (HMI) arrangements (e.g. degree of integration of the operator workstation / HMI);
- System servers (i.e. separate or common platforms);
- Software and application data (i.e. level of software development and application data configuration).

6.5 System Integration Types

The system integration types (reflecting the people, process and technology attributes) are classified as three (3) types as follows:

- Type 1: Traditional / Silo;
- Type 2: Physical integration;
- Type 3: Data and Visual integration;

The selection of the system integration type for the ROCC should be assessed for the desired rail operation.

6.5.1 Type 1 Silo

The silo integration type is where operations control staff are located at different control facilities (e.g. train control performed from a signal box at one location and power control performed from a traction supervision centre at another location). Integration is achieved mainly via personnel using voice communications (radio, telephone), messaging and email services. This approach is a common form of operational control arrangement in conventional railways. The type 1 integration model is shown in Figure 15.

Personnel are staffed at different locations with defined roles and responsibilities. Tasks are performed in accordance with defined work-role definitions and responsibilities with no multi-tasking.

Processes are generally administrative intensive. Information exchange between systems is typically performed by manual data entry (if at all). There is limited automation, and if so restricted to a specific system. From a CMMI point of view, this would be classified as a Level 1 or 2 organisation.

Operations control centre technology typically comprises multi-vendor systems with separate HMIs (each with own keyboard and mouse) with non-integrated operator display graphics. System equipment is generally located at different sites with little (or no) data integration amongst the systems. The use of legacy technologies is quite common.

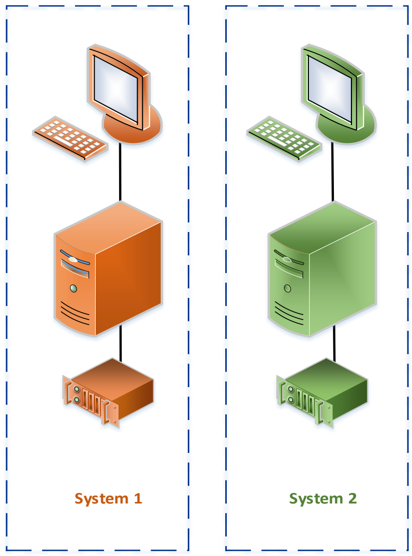

Figure 15: Type 1 Silo Type

6.5.2 Type 2 Physical Integration

The physical integration type is where operations control staff are co-located at a main ROCC facility where support from other locations (e.g. stations) may be provided. Integration is achieved mainly via personnel using voice communications (verbal / intercom) as they are near each other in the control room, supplemented with radio, telephone, messaging and email services. This approach is typical for many metro railways and heavy haul / freight railways. The type 2 integration model is shown in Figure 16.

Personnel for day of operations are generally co-located in the same control room facility. Tasks are performed in accordance with defined work-role definitions and responsibilities but with improved communication amongst the personnel.

Processes include improved coordination and situational awareness. There may be some limited data exchange between systems and some specific automation. From a CMMI point of view, this would generally be classified as a Level 2 or 3 organisation.

Operations control centre technology typically comprises multi-vendor systems with separate HMIs (each with own keyboard and mouse) but are co-located in the same facility. It is possible for operator displays to have a consistent look and feel. System equipment especially main servers are located in the same facility.

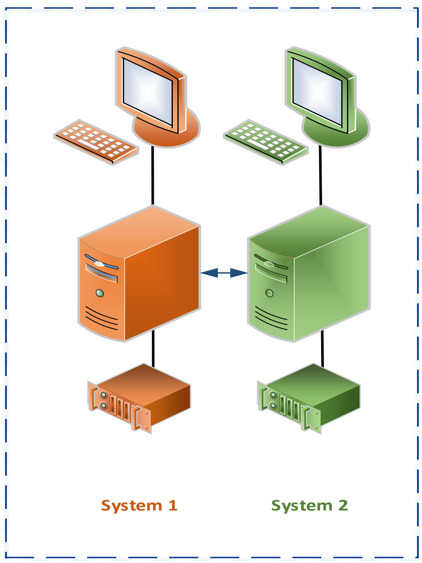

Figure 16: Type 2 Physical Integration Type

6.5.3 Type 3 Data and Visual Integration

The data and visual integration type is where operations control staff are co-located at a main control facility, where the operator HMI is integrated into a common workstation environment (e.g. may be one or two operator workstation types), and where key or routine tasks are integrated among systems (e.g. critical alarms, traction power isolations communicated to signalling system etc). Voice communications, messaging and email services are also used but key data items are transferred between systems to provide defined functions. The type 3 integration model is shown in Figure 17. This approach is common on modern metro railways where partial data and visual integration has been achieved (i.e. signalling and train control separated from power, facilities and communications control). However full integration using a common platform type is not widely used.

Personnel for day of operations are generally co-located in the same control room facility with support from other locations. Distributed or virtual control centre arrangements allowing multi-tasking may be possible (i.e. personnel can be located anywhere as long as they have access to a workstation and supporting communications facilities).

Processes allow for routine procedures to be embedded as system functions. Automation of data entry and transfer between systems can be achieved (e.g. tunnel ventilation coordination and control). From a CMMI point of view, a Level 3 to Level 5 organisation is possible.

Operations control centre technology typically comprises fewer-vendor systems where an integrated HMI workstation can be achieved (fewer keyboards and mouse) to provide improved situational awareness. Integrated operator displays can be achieved using multi-windowing, virtualisation, or common HMI / browser technology.

System equipment especially main servers are located in the same facility or distributed. Integration amongst the systems can be achieved via defined data protocols, application-programming interfaces, common middleware platform / service oriented architecture or cloud computing. Single vendor solution platforms are possible. An example of a Type 3 ROCC is shown in Figure 18.

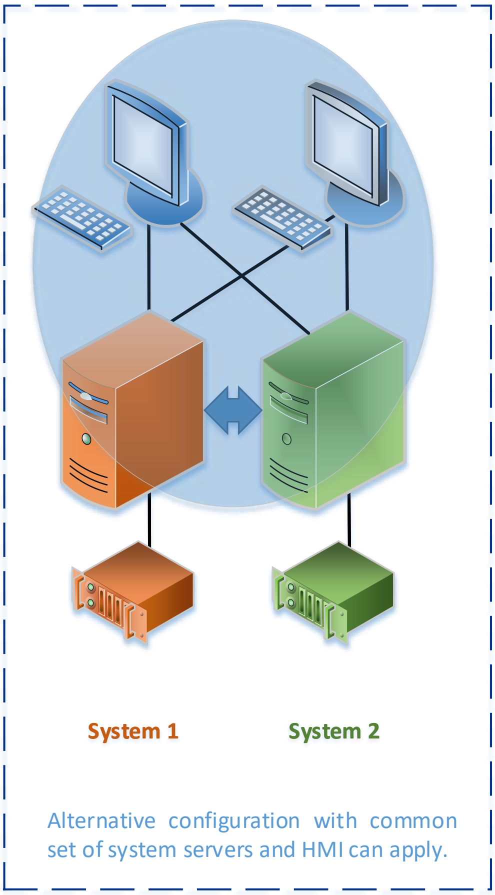

Figure 17: Data and Visual Integration Type

Figure 18: ROCC Type 3 Control Room Example

6.6 Comparison of System Integration Types

The advantages and disadvantages of each system integration type are shown in Table 1.

Table 1: Comparison of System Integration Types

Integration Type	Advantages	Disadvantages
Type 1: Silo	• Traditional; • Easier to implement (separate systems, separate contract packages); • Well understood.	• Performance can be constrained; • Coordination is likely to be more difficult (greater manual procedures); • Situational awareness is limited.
Type 2: Physical Integration	• Reasonably cost effective (cost mostly ROCC building itself); • Improved situational awareness due to co-location; • Easy to implement (separate systems, separate contract packages but in same facility); • Foundation for future integration.	• Procedural dependent, can be considered as multiple silos in the one room; • Lack of flexibility; • Some tasks continue to be manually onerous (e.g. consolidating alarm and event lists, coordinating traction power isolations with train control).
Type 3: Data and Visual Integration	• Improved situational awareness and coordination (e.g. common HMI environment); • Automation of key functions (e.g. automatic reactions to fire) reducing potential operator error; • Improved human factors, potential flexibility of operator roles; • Availability of common 'big data' for analysis (e.g. root cause analysis).	• Greater implementation complexity as requires concerted operational definition, system development, and change-management impact; • Concerns about sole-sourced supplier, or concentration of power with selected vendors; • Costly to implement if software development activities are required; • Requires high system availability to avoid any common point of failure.

6.7 Human Factors Consideration

A major consideration for the system integration is the application of Human Factors (HF). Human Factors is concerned with the interaction between humans and other elements of a system, in particular with those factors that may cause or contribute to human error. It involves user-centred design to minimise safety risk. Human Factors activities associated with the ROCC system integration include:

- Identification and review of applicable Human Factors standards, rail operator's policies, plans and procedures;
- Identification of key users and their associated task and communications to check that they are achievable, practical and safe under normal, degraded and emergency operations;
- Assessment of systems and equipment to ensure they are usable for operations and maintenance including control room layouts, operator workstation design and HMI / alarm management.

One of the key standards for control room design is the ISO 11064 Ergonomic design of control centres [3]. This standard covers principles for control room layouts, workstation, and other environmental and ergonomic requirements.

7 BACK-UP ROCC

One of the key considerations to implementing a ROCC is the requirement for a Back-up ROCC (i.e. is a Back-up ROCC really required?). The Back-up ROCC can provide disaster recovery for the ROCC thereby providing operating continuity and enhancing resilience where the ROCC is impacted. There are usually two types of events that the Back-up ROCC is best suited as follows:

- The need to evacuate the ROCC control room (e.g. reported gas or water leak, air conditioning failure, or other threat), where the operational systems and technology assets remain available but are not impacted;
- The need to evacuate the ROCC where the operational systems and technology assets are impacted (e.g. complete power failure, fire, flood etc).

For the above events, the Back-up ROCC takes over control until the main ROCC can take back the control.

Whilst the Back-up ROCC has benefits, a Back-up ROCC is expensive to implement and maintain. There are logistics, personnel and change over time considerations to effect the transition from the ROCC to the Back-up ROCC. To ensure that it is available when required, regular updates and maintenance of the back-up systems and change over to the Back-up ROCC at regular intervals is required.

To realise the full benefit of a Back-up ROCC other uses for the Back-up ROCC should be considered such as a training and simulation facility, system test facility, or operational development facility. Alternatives to a Back-up ROCC include use of local control facilities, portable facilities or an essential services back-up facility (e.g. back-up dedicated train control system located in another building).

8 CONCLUSION

Railway operations are complex, there are many moving parts and dependencies, fulfilling an operations plan to achieve consistent normal operations is a challenging task. It's not always a simple path for rail operators to implement a ROCC meeting their objectives and providing the desired benefits. Rail operators may face several impediments as follows:

- Existing / legacy systems may be difficult to modify, relocate or integrate;
- Constrained infrastructure (i.e. lack of a high-speed data network);
- Restrained workforce or traditional organisational culture have a reluctance for change;
- Other commercial, financial, or regulatory constraints.

The benefits of implementing a ROCC to achieve future rail operational success includes:

- Providing a continually improving and resilient service;
- Improving situational awareness to effectively respond to incidents;
- Enhancing organisational culture and capability;
- Providing excellent customer experience.

Applying the ROCC for resilience framework described in this paper can overcome these impediments and provide the definition of success for rail operations to ROCC and role.

9 REFERENCES

References used in this document are:

1. IEC 62290-1: 2014 Railway applications – Urban guided transport management and command/control systems – Part 1: System principles and fundamental concepts, and all parts.
2. CMMI: https://cmmiinstitute.com/cmmi/intro
3. ISO 11064-1: 2000 Ergonomic design of control centres - Part 1: Principles for the design of control centres, and all parts.