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Workplace analysis and business process re-engineering: Railway Control Centres

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Abstract

Kowloon-Canton Railway Corporation (KCRC) in Hong Kong is presently responsible for the safe and efficient transportation of large volumes of people. It is one of the very few mass transit railway operators in the world which can be operated without requiring financial subsidy from the government. In the year 2003, KCRC will open a new 30 kilometer railway that will connect Hong Kong with the northern western suburban New Territories, namely the West Rail (WR) Phase I. Railway monitoring and control functions will be performed via a centralized remote control centre supported by a number of smaller control rooms located in stations and depot. The new control centres will be designed and built to support the new railway operations. In creating each new control centre, it is essential to consider to means to reduce operator error and to enhance the man-machine interface. This paper reviews the techniques used to conceptualise the processes in each control centre given that none of it exists today. These modeling techniques make it possible to understand the interaction between the operators and the proposed control and communications systems to enable decisions on staffing levels, ergonomics and other facilities to be assessed and determined. The approach adopted is in line with the modern concept of Business Process Re-engineering. Normal and emergency operational considerations are also modeled to formulate an accurate representation of the working environment. Based heavily on the systematic methodology adopted by human factors experts, the method has proved very useful in completing the conceptual design for all the operations control centres in the new KCRC West Rail project.

1 Introduction

The West Rail (WR) network, like many other modern and advanced mass transit railway systems in the world, is planned to be controlled via a remote control centre and supported by a number of local setallite control points. These control centres are called Operation Control Centre (OCC) and Station Control Rooms (SCR) respectively. The Operation Control Centre is thus acting as the central control hub for the whole railway which is targeted to carry more than 400,000 passengers when the railway is opened in 2003, which is going to rise to more than one million in 2010. All these control centres will be playing a very significant role in ensuring the railway can be operated in a safe, yet efficient and effective manner meeting the extraordinary high standards which have been set forth by both the railway operators and their passengers in Hong Kong.

All the basic design requirements are captured in the Design Criteria[1] for the WR project, while the Operational and Maintenance Plan[2] states clearly all the requirements for operating and maintaining this new railway network. Though the Plan is a live document which is being updated as the external situations and conditions are changing, it lays down the foundation for the design of the WR system including all the control centres involved in the network.

2 Business process re-engineering - Control Centre Design

The technical design of the control centres was started back in mid 1997 when a consultancy contract was awarded to a system consultant who is tasked to carry out a thorough "technical study" on the technologies to be adopted for the various control centres with an aim to produce a "**Design and Build**" functional specification for tendering by mid 1998. In the process of developing this specification, both the KCRC WR design management and the WR operations management teams identify the needs to critically review the functional requirements for the various control centres in order to design the organisational structure as well as the technical provisions using modern technologies in the control centres.

In reviewing and hence defining the functional requirements for all the control centres in WR network, a new approach which is considered to be drastically different from the traditional way has been adopted. This approach is seen to be in line with the current philosophy of Business Process Re-engineering (BPR), with the first tasks being the analyses of the business processes to be performed in the control centres rather than going directly into specifying the technical provisions taking the control centre operational model being established in other railway systems as the WR model. We believe every single railway system has unique differences in operating procedures. This is mainly due to the variations in

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environmental conditions, passenger expectations and type of services to be provided. Booz Allen and Hamilton was then awarded a contract to perform the study on the Control Centres design.

The approach taken involve two major steps, namely Workplace Analysis Study and the Bench-marking Study. Workplace analysis aims to analyse the tasks required to be performed in each control centre and a technique known as Hierarchical Task Analysis is adopted in defining the task structure. Communications requirements, both verbal and written, together with the expected workload exerted on each position within the control centres are quantified in order to define the manning level as well as the equipment provision requirement. As WR is a new railway to be built, analyses that have been carried out in this study were based on the data / references gathered on railway networks of similar nature and the experience of the consultants and the KCRC WR design team involved in the study. After the completion of the workplace analysis study, a bench-marking exercise is conducted. This includes round the world tours to a selective group of control centres, each of which has unique features that WR would like to explore further. Some twelve different mission critical control centres covering Asia, Europe and North America have been visited and information have been exchanged with their respective operational and technical personnel. Environmental issues such as lighting, temperature and acoustic aspects in the design of the control centres were also studied in details in this study.

Based on the results of the analyses together with the outcomes of the bench-marking study, a set of recommendations are then produced. The following sections describes the processes and the recommendations made in details which cover the Operation Control Centre, the Backup Control Centre, the Incident Management Room, the Station Control Room, the Platform Supervision Booth and the Depot Control Centre of the WR network.

3 Workplace Analysis Study

Workplace analyses were performed with reference to the existing East Rail system to define the workplace demands of the Operations Control Centre (OCC). Once defined, the results will be adapted for the future West Rail OCC facility design specifications presently being developed. To accomplish this, KCRC commissioned a human factors based study on the OCC workplace using three systematic analyses:

- Hierarchical Task Analysis

- Communication/Information Flow Modeling
- Workload Analysis.

The West Rail Control Centre study was based on a two pronged methodology. In addition to the three human factors analyses noted above, a control centre site visit bench-marking study was performed and documented. The two pronged approach identified unique KCRC operational considerations and specific attributes which, as identified from the sites visits, will be applied to West Rail. Results from both of the studies provide recommendations for ergonomic control centre design specifications.

3.1 Hierarchical Task Analysis

Hierarchical Task Analysis (HTA) is a systematic technique used to define tasks and critical operator-machine and operator-organisational interfaces (e.g., equipment, departments, management, etc.). As with all human factors analysis and design, HTA assesses key parameters that are required for a complete evaluation, these include; the requirements of the system, identification/description of tasks and users, and task objectives. For KCRC, the HTA process involved making some first level decisions on the critical functions performed and macro level tasks that were required to meet the system objectives. Thus, HTA was performed on selected OCC staff positions as agreed upon by KCRC management staff. Subsequently, critical scenarios were identified and evaluated with respect to the balance of responsibilities for functions and operations staff. The outcome from the HTA was a well defined breakdown of each selected job position and its critical task functions.

When implementing the HTA, job identification was completed through key operational staff managers. Decomposition of each individual position required an accurate job description and operational breakdowns of standard and emergency tasks. However, the accuracy of the HTA is only as thorough as the job description or job position observation. Further job-task description is developed using the proceeding step, communication/information flow modeling.

3.2 Communication/Information Flow Modeling

Using the results of the HTAs to define job positions, tasks, and sub tasks; the communication/information flow methodology was then applied to determine the links and frequencies between the communication elements within the existing East Rail OCC. Using a time-based methodology, each

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selected position documented communication destination/origin, frequency, and method. These results yielded a breakdown of the communication factors for each position which were then applied to the requirements of each position to complete the critical communications.

Applying Visio® flow software to different OCC staff which, based on the HTA, created a database to create accurate documentation and graphical modeling of the multiple job position/equipment interactions. Additionally, applying this method to equipment needs and job-task design, the workplace could then be ergonomically optimized for each position. This step is subsequent to the proceeding analysis, workload assessment.

3.3 Workload Assessment

Combining the HTA and communication/information flow analysis results, a structured subjective workload metric was developed.. Mental workload is the demand placed upon individuals while performing a task. Under extreme workload conditions a person can become "overloaded" often leading to decreased human reliability and increased errors. Subjective mental workload analysis measures direct or indirect queries of the individual for their opinion of the workload involved in a task. This technique can assess task attentiveness, task overload, and task deprivation. Applying this workload assessment technique used by the aircraft, nuclear power and military sectors can provide both quantitative and qualitative analyses on the operator workload.

A subjective mental workload assessment was administered to each selected East Rail OCC position. The assessment survey measured the required cognitive attentiveness per time unit for each task identified in the hierarchical task analysis. The format allowed the staff to measure their own situation using ticks and checks to document the workload easily. Since the method quantified the workload at each position, the three separate eight hour shifts were required to participate in the assessment. Thus, the peak and non-peak hour demands were accurately represented, providing a further level of analysis and information to be applied during the design and development stages of West Rail.

4 Bench-marking study

In order to allow the study team an opportunity to appreciate and compare the various aspects of modern control centre design, a series of site visits was attended. While the successful experiences of the East Rail operation provided a good starting point for the integration of various control centre considerations, KCRC appreciates that the West Rail Project will pose her own unique set of operating demands. Thus, KCRC desired to compare her initial intentions with best practices employed at similar world class control centres (i.e. bench-marking). Thus a state-of-art technology review was proposed. The sites chosen included:

- Transpole, Lille, France
- TGV, Lille, France
- Metro Bilboa, Bilboa, Spain
- LUL Jubilee Line Station and Central Control Centres, UK
- National Grid Control Centre, UK
- Massachusetts Bay Transportation Authority, Boston, USA
- Bay Area Rapid Transit District, San Francisco, USA
- NASA Control Centre, Houston, USA
- Teito Rapid Transit Authority, Tokyo, Japan
- Osaka Municipal Transportation Bureau, Osaka, Japan
- East Japan Railway Company, Shinkansen, Tokyo, Japan
- SMRT Station and Central Control Centres, Singapore

The visits also covered the investigation of the environmental design of the various world class control rooms. The following aspects were of particular interest with respect to environmental factors study :

- Lighting
- Noise impacts
- Thermal conditions
- Color coordination (including consoles, carpets, wall finishes)
- Staff Amenities (such as rest rooms, mess rooms, pantry faciltities).

These site visits allowed the study team to evaluate the positive attributes and potential improvements that could be implemented on the West Rail Control Centres. The visit team comprised of KCRC WR Operational representative, KCRC WR architects and KCRC WR control centre design engineer as well as the Control Centre study consultant personnel. The composition of the visiting team was made up in such a way that a full spectrum of issues was covered and the proposal made for control centres design would be an integrated whole taking all the necessary aspects into consideration.

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5 Findings

Applying business process re-engineering : workplace analyses and bench-marking observations, several recommendations were made to West Rail Control Centres design and build. The results are categorized as; job/task design, human/workstation ergonomics, and environmental design considerations which are further described below. Full details can be found in the Control Centre Study - Final Report [3].

5.1 Job/task design

It was determined that the KCRC West Rail OCC staff will be required to perform numerous tasks of varying degrees of criticality, reliability and timeliness. Hierarchical Task Analysis determined that job tasks during off-peak operations will be designed so that vigilance be maintained in order to facilitate situational awareness. Information/communication flow model revealed that during peak operations and emergency response situations, the demands placed upon the OCC staff will become a significant factor determining if the appropriate response is performed. Furthermore, the workload assessment found that the stress and demands placed on individual OCC positions are significant and potentially exceed the capabilities of the human operator. Thus, human-task criteria are being considered in the design phase and is the ultimate objective of the workplace analysis and business process re-engineering study.

5.2 Human/workstation interaction

Our current design is that the West Rail OCC workstation consoles will house four primary functions, these include; Train Control, Telecommunications, Main Control Systems and Maintenance with minimal yet sufficient amount of integration. This approach of utilizing limited integrated man machine interface eliminates the usual problems in designing and implementing systems interfaces among different contractors and hence greatly increases the chance in delivering these control systems on time and within budget. With an appropriate level of integration, the operating staff can put more focus on tasks which require additional workload to control or monitor. This functionality will be used to reduce the number of operators, yet remain focused on critical tasks. Additionally, the workstation console and seating specifications will meet or exceed ergonomic standards for computer terminal use, including; ISO/ANSI standards and Hong Kong population anthropometric parameters.

5.3 Environmental design consideration

It was determined during the bench-marking study that specific design considerations be accounted for during design specifications. Specific design considerations include; observation/viewing areas, circulation of staff and console locations, and decision-making strategies with concern of workstation layout. Furthermore, West Rail should include an overview screen display to present the Controllers and Supervisory Staff with a common view on the overall system status and the critical operational scenario.

Control centre lighting for West Rail should focus on three main objectives; safety, performance, and comfort. Use of diffused natural light to supplement artificial light should be considered when defining room layout, overview screen display type and artificial control centre light. Facilitation of control centre natural light is a consideration West Rail is in the process of defining. Additionally, incandescent or quartz halogen task lighting should be provided for hard tasks and hard copy review.

6 Conclusion

Through this systematic workplace analysis study, a very vigorous exercise, from the definition of the tasks to be performed by each individual operator position in each control centre through to the determination of the environmental conditions such as the possibility of the provision of the diffused nature light in the control centre to ensure the tasks so identified can be carried out in the most effective and efficient manner, has been taken place. This proves to be a very useful step taken in the designing of a new control centres which can be "fit for purpose".

The outcomes of the study identify certain areas which have not been considered in details before. These, in WR situation, include the integration approach (non Universal Workstation Approach), the manning level and hence the organisational structure (different from the ER structure), the possibility of having diffused natural lighting setup in the OCC (used to be all enclosed under controlled lighting conditions) and the integration of operation and maintenance activities in OCC (used in separate operational and fault report centres). These recommendations have been well accepted by the KCRC WR management and have been translated into various requirement clauses in different WR contracts concerned.

The last, but not the least, it is worth noting that the involvement of the user representative in the process is considered to be one the most important and critical success factors in the whole exercise. Their commitment and continuous support given to the design of the control centres should start from the initial stage of the project and this can only be achieved if they are considered to be part of the design team throughout the whole project life-cycle. As a conclusion, though the approach adopted, like any other Business Process Re-engineering process, is both manpower intensive and time consuming, it is believed to be of utmost importance and significant benefits in the future operation of the world class West Rail network of KCRC.

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