Abstract:

Competency Modeling (CM) is a systematic process through which the knowledge, skill and mindset attributes of effective workers in an industry segment are identified and defined in behavioral terms. Two CM’s were developed to provide insight into the key knowledge, skill and attitudinal attributes of effective engineering practitioners and operations professionals in the North American rail industry. The models include core competencies that are common across organizations in the North American rail industry. For each competency, the defining knowledge, skill and attitudinal attributes are presented. In addition, confirming behaviors are presented to provide a benchmark against which one can measure the presence of the competency in practice.

These models are important and have implications for workforce development and continuing engineering education (CEE). Through CM, CEE providers can identify
learning needs within the professional community, and in turn, better structure CEE and undergraduate and graduate program curriculum and instruction. This is significant because the North American railroad industry is at a critical juncture with regard to their workforce. Today, a significant proportion of rail industry professionals are at or near retirement age. And a 2011 Federal Rail Administration study identified the aging workforce and knowledge transfer as the number one rail workforce concern.

Compounding the workforce issue is the reality that there are relatively few undergraduate rail transportation engineering programs in the US, and the reality that the number of freshly minted rail engineers and operations professionals is not sufficient to replace those who will leave the industry in the near future. As a result, the rail industry will rely heavily on continuing education as a means to fill the workforce development gap. The authors will discuss how CM will be used to create CEE models strategies, and structures to effectively develop engineering professionals in this economic segment.

**Introduction**

Competency Modeling (CM), as a foundation for talent management is becoming commonplace. With applications in recruiting and staff development, performance evaluation, and strategic workforce planning, CM is a critical element of the “Talent Management” paradigm that has been adopted by many organizations. CM also fits well with the structured and measured approach to certificate and certification programs offered by educational institutions and professional organizations.

The Department of Engineering Professional Development (EPD) at the University of Wisconsin-Madison has recently completed competency models that define engineering and operations professional roles in the North American rail transportation industry. EPD is a recognized leader in providing continuing engineering education for the rail industry, and our growing portfolio of rail engineering courses are increasingly popular in an industry experiencing significant turnover. Our intent is to use CM to guide curriculum and program development, and to define functional knowledge and skills applicable to most organizations.

Academic institutions that sponsor CEE programs are uniquely qualified to engage competency models in the research, development, implementation, and quality assessment of their programs and services. Academic institutions are able to engage research methods and practices to competency model development. In addition, ECE organizations can benefit from engaging academics from disciplines such as Organizational Sociology, Psychology, and Education, among others, in the design, development, and implementation of a competency model.

This paper will provide an overview of CM, its application in ECE, and provide recommendations for using competency models as a foundation for ECE.
CM Overview

CM dates back to the pioneering work of David McClelland where he challenged the long-held practice of using aptitude or standardized intelligence tests as a predictor of future job performance (McClelland 1973). McClelland found that by using criterion-referenced instruments that focus on attributes derived from behavioral indicators of capable employees, he could more accurately predict success in a specific job. His work became the foundation for ongoing application of CM today.

Competency models differ from other approaches to job task assessment in that they focus on performance, rather than credentials, and define exemplary, rather than minimal performance. In addition CM can be used to evaluate the capabilities of organizations as well as individuals. A fundamental concept in the use of competency models is that the models support the organization’s core mission and are closely aligned to its strategic direction. Similarly, competency models are rooted in the corporate culture. Therefore, the attributes that make a person successful in one organization may be the attributes that make them less than successful in another.

There are a variety of approaches an organization can take in employing competency models. “Organizational competency models” examine the attributes and core capabilities across the enterprise and are used guide strategic decisions and direction. “Functional competency models” are generally applied vertically within an organization to a broad class of employees with similar functions, for example, “engineering”. “Role-based competency models” are applied horizontally within and organization to a broad class of employees with similar roles, for example, “managers”. And finally, “job-specific competency models” define the attributes of workers within a specific job role, for example “software design engineer”.

**Competencies** form the basis for competency models. Though many definitions exist for competencies and competency models, our projects employ the following definition:

> “Competencies are identified knowledge, skills, abilities, and mindsets, evaluated through demonstrated behaviors, which directly and positively contribute to the success of the organization and to the success of employees in their job role, position, and function.” [Univ. Wisconsin]

Within this operational definition, competencies may fall into one of three broad categories. These include, Knowledge, Skills, and Mindsets. In this paradigm, “knowledge” is defined as what you are aware of - information known within a content area typically from facts or experience. “Skills” represent the physical and technical ability to execute the physical and / or mental tasks associated with a role or function. And “Mindsets” includes the attitudes, beliefs, values, and perceptions that are demonstrated in behavior.
Literature Review

There has been a significant study of training and development within the rail industry. Workforce studies have primarily focused on craft and skilled labor, though recent research has included rail professionals, in particular people in engineering and operations / logistics roles. In this literature review we will examine various aspects of the rail workforce and how those could impact CEE in the rail transportation industry.

Present Understanding of the Decline in Railroad Industry Workforce Numbers and Skills

The United States railroad industry is very unique; it has different traditions, rules, working conditions, and human performance requirements than other industries (Sussman & Raslear, 2007). The railroad industry has a military organizational model with a strict command-and-control structure and is one of the most highly regulated industries in the United States (Federal Rail Administration, 2011; Sussman & Raslear, 2007; Kessides & Willig, 1995). Since the 19th century, the rail industry has been be a major catalyst for the national economy; moving people, goods, and services and creating jobs nationwide (Federal Rail Administration, 2011).

The growing demand of both freight and passenger services has left the industry to face many challenges. Presently one of the major challenges to the railroad industry is the availability of a well-educated and trained engineering workforce (Lautala, 2007). The abundance of trained railroad workforce that once existed is long gone. There has been a major reduction in the railroad industry workforce, from close to three million in 1946 to now only fewer than 300,000 (Popkin, Morrow, Di Domenico, & Howarth, 2008).

The next section reviews the following major reasons for the decline in the workforce numbers and skills of the railroad industry as identified in the literature: demographic changes, industry image, career awareness and training, workforce diversity, and technological innovation.

Demographic Changes in the Railroad Industry

As the U.S. population faces a major demographic shift from a younger to an older population, there has been an increase in the number of older adults approaching retirement or retiring in the railroad industry workforce. In 2004, the Association of American Railroads projected that 40 percent of railroad employees at that time were eligible to retire by 2014. Railroad industry companies, organizations, and government agencies have recognized the aging workforce issue.

However, the current recruitment and hiring practices have not prepared the railroad industry for this shift (Federal Rail Administration, 2011; Kelser, Stewart, Chapell, and Parker, 2011); as such there are significant skill gaps and a small pool of potential
qualified workers at all levels. In addition, the Railroad Retirement and Survivors’ Improvement Act (2001), which allow for railroad employees to retire at age 60 with 30 years of experience, has contributed to the increase in retirements (Popkin, et al., 2008).

During the 2012 National Transportation Workforce Summit, Ed Hamberger referenced that twenty-three percent of railroad workers are between the ages of 55 and 64 and how the industry struggled to fill their 15,000 open positions in 2011 (Council of University Transportation Centers, 2012). The demographic changes have led to problems in capturing and transferring specialized knowledge and historical perspective between the current and next generation of railroad workforce and keeping the experienced professionals up-to-date on emerging technologies (Council of University Transportation Centers, 2012; Federal Rail Administration, 2011).

**Industry Image**

The misconception of the railroad industry as being antiquated and limited in opportunities has led to challenges in recruiting the next generation of workforce (Council of University Transportation Centers, 2012). The lack of rail companies’ presence on the Internet also contributes the misconception. The demanding and unpredictable work schedules have made it hard to attract and retain talent successfully over time thus leading to high attrition rates especially within the first five years of employment (Council of University Transportation Centers, 2012; Federal Rail Administration, 2011; Popkin, et al., 2008). In addition, pay is no longer an incentive for attracting workers (Popkin, et al., 2008). The lack of work-life balance makes rail unattractive when compared to other industries (i.e. information technology) to the next generation of railroad workforce. As discussed at the 2012 National Transportation Workforce Summit, the railroad industry will need to rebrand itself and employ different management approaches (i.e. flexible work arrangements) to appeal to the younger generation.

**Career Awareness and Training**

Training the next generation of railroad workforce to replace the current aging railroad workforce is a major challenge. Most of the training is done on the job and there are very few established mentoring programs. Furthermore, most universities eliminated railroad engineering from their curriculum several decades ago and there are only handful of U.S. institutions universities with railroad engineering and operations education programs, research programs, and course offerings (Federal Railroad Administration, 2011; Lautala, 2007). However, these education institutions still experience challenges responding to the changing industry needs as it relates to knowledge, skills, and abilities due to financial and institutional constraints as well as the complexity associated with trying to attend training course and work (Council of University Transportation Centers, 2012). The shortage of educational programs has led railroads to hire and train candidates with diverse educational and experience backgrounds (Lautala, 2007).
One of the greatest workforce needs in the railroad industry is the demand of engineers especially civil engineers in design, construction, and management tasks at Class I railroads, regional and short line railroads, commuter and transit systems, state and federal government agencies companies, consulting engineering firms, material and equipment suppliers, and construction firms (Lautala, 2007). Unfortunately, the supply of engineers is not sufficient to meet the demand. Although there was an increase in the number of overall bachelor engineering degrees granted in 2011, degrees granted in civil engineering only accounted for approximately fifteen percent of the total (American Society of Engineering Education, 2012). In addition, current civil engineering curricula rarely provide railroad related engineering courses; leaving some students without any exposure to railroad topics (Lautala, 2007).

There are also no national training standards available (Federal Rail Administration, 2011; Kesler et al., 2011). The lack of knowledge about what standard and specialized transportation competencies and skills are needed to be successful in the railroad industry also hinders the growth of potential qualified workers (Council of University Transportation Centers, 2012). This lack of knowledge leads to no or insufficient training on these competencies and skills. Career awareness is another major hindrance in recruitment of the next generation of railroad workforce. Although some people learn about railroad career opportunities in K-12 school, community colleges, universities, and student organizations such student chapters of American Railway Engineering and Maintenance-of-Way Association (AREMA), it is often after they have made a decision about their desired career path (Council of University Transportation Centers, 2012).

**Workforce Diversity**

There is a shortage of women and minorities working in the railroad industry workforce (Federal Railroad Administration, 2011; Kelser, et al., 2011). It appears that over the years, railroad companies and agencies lack the ability to recruit and attract a diverse and inclusive workforce. This is partially due to railroads use of the traditional recruitment sources such as “father and son” or nepotism (Federal Railroad Administration, 2011; Popkin, et al., 2008). Since work diversity is of concern to the industry, companies have developed and implemented diversity programs, such as affinity groups to contribute to diverse recruiting, college outreach, and new hire assimilation (Federal Railroad Administration, 2011). However, more effort is needed in work diversity.

**Technological Innovation**

The advancement in technology and its increase use in the railroad industry play a vital role in attracting and recruiting the workforce. While emerging technologies have the potential to attract and retain workers by making work conditions better through streamlining processes, they also require certain skills to operate (Council of University Transportation Centers, 2012). The new technologies can eliminate the need for certain professions, create job opportunities for the next generation of railroad workforce and cross-disciplinary workers, and lead to skill gaps in the existing workforce (Council of
University Transportation Centers, 2012; Federal Railroad Administration, 2011). Consequently, retraining of existing workforce is necessary to keep pace with industry’s tools and products (Council of University Transportation Centers, 2012).

**Data Quality**

It is hard to project the supply and demand of railroad industry workforce without the availability of data. According to Kesler et al. (2011) railroad workforce trends, total actual attrition, total hires, diversity hiring statistics and the percentage of total attrition related to retirements is not available industry-wide. As such this lack of information limits the advancement of the workforce as well as the identification and understanding of competencies and skills needed.

**Competencies in the Rail Industry**

Competency models are generally structured in a hierarchical fashion. In this arrangement, a competency “dimension” is comprised of a group of related “competencies”. For example, a dimension may include capabilities in business acumen; and competencies within the dimension may address capabilities in the areas of finance, business management, and business development. These competencies are further clarified through defining “attributes”. Attributes include knowledge, skills, and mindsets. For example, the ability to develop a financial model is a skill that relates to a finance competency. At the lowest level of the hierarchy are “behaviors”. Behaviors are observable actions that indicate the presence (or absence) of an attribute. An example of a financial skill behavior is, “consistently communicates accurate project financial forecasts.” Behaviors are the observable, measurable, component of the model.

Within the rail transportation industry, our team developed two competency models, the first for engineers; defined as persons with a minimum of a bachelor’s degree and working in roles related to an engineering discipline. The Rail Transportation System Engineer Competency Model was developed to provide insight into the key knowledge, skill and attitudinal attributes of effective engineering practitioners in the rail industry. Given the wide range of engineering roles and responsibilities, as well as the highly varied nature of organizations within the industry, this model is designed to provide a “generic” description of competent practice as well as exploring aspects of engineering sub-disciplines common to the rail industry.

Though the model gives a comprehensive, yet general assessment of competent practice within the industry, it will not address every engineering job role, this is because competent practice is couched within the culture of the employer, and not every attribute described here will apply to every situation. The model includes six core competencies that are common across organizations in the rail industry. Similarly, the model includes competencies associated with five engineering sub-disciplines.
The overall structure of the competency model provides for consistent definition of competencies and their attributes. But since competent practice is defined within the context and culture of the local organization, individual competencies, and level of detail associated with them will vary based on organizational characteristics. The Rail Transportation System Engineer model was created for general application within a broadly defined industry, therefore the model contains “generic” knowledge, skill and value attributes.

In this model, six general and five specific (sub-discipline) competencies are described. These include:

- Domain Knowledge – Engineering
- Domain Knowledge – Engineering Sub-Discipline
  - Track and Infrastructure Engineering
  - Rolling Stock and Traction Engineering
  - Communication and Rail Signal Engineering
  - Engineering of Bridges and Structures
  - Control Systems Engineering
- Commitment to Safety
- Project Management
- Personal Effectiveness
- Commitment to Standards
- Utilization of Engineering Tools and Support Systems

The Rail Transportation Operations Manager Competency Model, our second model, was developed to provide insight into the key knowledge, skill and attitudinal attributes of effective operations professionals in the rail industry. Given the wide range of roles and responsibilities, as well as the highly varied nature and structures of organizations within the industry, this model is designed to provide a more “generic” description of competencies common to effective practitioners while exploring competencies of common operations “sub-disciplines”. And again, because competent practice is couched within the culture of the employer, not every attribute described in the model will apply to every operations managerial role. Rather, the model gives a comprehensive, yet general assessment of competent practice within the industry.

The model includes seven core competencies that are common across organizations in the rail industry. Similarly the model contains competencies associated with five sub-disciplines. For each competency – the knowledge, skill and attitudinal attributes that define the competency are presented. In addition, confirming behaviors are presented that describe how one can demonstrate the presence of the competency in professional practice.

The overall structure of the competency model provides for consistent definition of competencies and their attributes. But since competent practice is defined within the context and culture of the local organization, individual competencies, and level of detail associated with them will vary based on organizational characteristics. The Rail
Transportation System Operations Manager model was created for general application within a broadly defined industry, therefore the model contains “generic” knowledge, skill and value attributes.

In this model, seven competencies and five-sub-discipline competencies are described. These include:

- **Domain Knowledge - Operations**
- **Domain Knowledge – Operations Sub-Disciplines**
  - Communications and Signal Operations
  - Yard and Terminal Operations
  - Asset Management
  - Information Management
  - Traffic Planning and Logistics
- **Commitment to Safety**
- **Business Acumen and Customer Awareness**
- **Project Management**
- **Personal Effectiveness**

**Summary**

EPD has developed a number of competency models to guide engineering curriculum in the academic setting as well as professional development for engineers and technical professionals in private and public-sector organizations.

In developing these models, EPD staff gathered and reviewed a large amount of qualitative data. This included information from the competency modeling literature and benchmarked models used in a number of technology-based companies and agencies. EPD has incorporated aspects of the “Bodies of Knowledge” promulgated by relevant engineering societies and professional organizations. In addition, EPD performed behavioral interviews with industry professionals and reviewed job descriptions and current job postings within the rail industry.

The Rail Transportation System Engineer and the Rail Transportation Operations Manager Competency Models are generic in nature and provide a more holistic approach when compared to job task analyses and skill checklists that are common to the rail industry. The models have a hierarchical in structure, with competencies at the top. Each competency is then made up of attributes; that provide boundary, scope, and definition to the competency. Attributes describe knowledge, skill, and attitudinal characteristics of competent practitioners. Attributes are then further clarified by confirming behaviors.

For CEE, the competency models provide guidance to the knowledge and skill needs of competent practitioners within the industry. With this insight, organizations can develop targeted learning and professional development activities to enhance the performance and effectiveness of the rail industry workforce.
References

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