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Chapter

Introductory Chapter: KM in Mission Critical Environments - Process vs. People!

Ali G. Hessami

1. Introduction

1.1 Safety

Safety is regarded as freedom from unacceptable risk of harm to humans and is the focus of much regulation and standardisation. Prevention of harm to people is therefore a moral as well as a legal issue; however, increasing complexity in modern products and systems poses a major challenge to the assurance of safety in mission critical systems.

1.2 Security

Unlike safety that is purely human focused, security is regarded as freedom from unacceptable risk of harm to people, loss to business and property or the natural environment. Unlike safety, security is characterised by malicious intent within the cyber, physical and organisational context and as yet not generally regulated. However, in the same manner as safety, assurance of security of complex products and services is another major challenge in mission critical systems.

1.3 Environmental conformity

Since the dawn of industrial revolution, the scale of mankind's influence on the natural habitat has increased significantly. The assurance of environment in complex products, systems and services is now regulated and under the protection of laws and government agencies. Respect for life and environment now constitutes another dimension of concern in any mission critical endeavour.

1.4 Synergies

The systemic and systematic identification, assessment and mitigation of safety, security, environmental and business risk issues under an integrated framework render enhanced integrity whilst posing significant savings in costs and time. In this setting, we explore the significant roles of the human agents and the application of pertinent knowledge to underpin success in a mission critical environment.

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2. The human impact

Given the role of the human agents and the pervasive interconnectedness and complexity of most modern products, processes and systems, we propose a radical shift of emphasis from hardware, software, products, systems and process/testing to the human attributes and operations that conceive, design, develop and deploy complex products and services.

The foremost contemporary management visionaries have labelled today's global economy as one in transition towards a "knowledge economy". During and post transition, knowledge resources such as know-how, expertise and innovation will increasingly be regarded as critical economic resources.

We refer to the totality of the abilities, know-how and attributes that empower people to successfully and consistently perform duties assigned under a role as competence. Competence is defined by the European Commission as the capacity to use effectively experience, knowledge and qualifications. A competent person would achieve the desired outcomes consistently, efficiently, every time or more often than not, satisfying or exceeding the expectations of the clients over varying circumstances. In this spirit, competency is the overall ability to generate success, satisfaction, value and excellence from the application of knowledge.

The systematic acquisition, assessment, development and management of competence pose a challenge beyond the traditional education, training appraisals and curriculum vitae. This is particularly pertinent in safety and mission critical roles where much rests on the performance of those tasked with specifying, developing, managing, deploying, operating or supervising an entire project, operation or mission. To this end, some new industry standards have emphasised the assurance of people competence, an emerging sensitivity that is bound to spread to many other facets of technological and service sectors.

There's a need for a new systemic vision in this arena. This paper develops and proposes a systems framework for ensuring the right entities are tasked with the critical roles in the overall life cycle of a complex system to enhance confidence and trust in the desirable properties such as safety and security. It describes the emerging competence requirements in European standards on software and hardware/system safety and provides a framework for compliance principally aimed at safety and integrity assurance.

3. Competence

The European Guide to Good Practice in Knowledge Management [1] defines competence as an appropriate blend of knowledge, experience and motivational factors that enable a person to perform a task successfully. In this context, competence is the ability to perform a task correctly, efficiently and consistently to a high quality, under varying conditions, to the satisfaction of the end client. This is a much more demanding portfolio of talents and capabilities than successful application of knowledge. So a competent person is much more than a knowledge worker. Competency may also be attributed to a group or a team when a task is performed by more than one person in view of the multi-disciplinary nature, complexity or the scale. A competent person or team require a number of requisite qualities and capabilities as follows:

1. The domain knowledge empirical, scientific or a blend of both.

2. The experience of application (knowing what works) in different contexts and the requisite skills.

3. The drive, motivation to achieve the goals and strive for betterment/excellence as well as appropriate behaviours such as teamwork, leadership, compliance with professional codes, etc.

4. The ability to adapt to changing circumstances and demands by creating new know-how.

5. The ability to perform the requisite tasks efficiently and minimise wastage of physical and virtual resources.

6. The ability to sense what is desired and consistently deliver a high quality to the satisfaction of the end client(s).

The right blend of these abilities renders a person or group of people (a team) competent in that they would achieve the desired outcomes consistently, efficiently, every time or more often than not, satisfying or exceeding the expectations of the clients over varying circumstances. Such persons/groups will be recognised for their mastery of the discipline and not just considered a fount of relevant knowledge often characterised by qualifications. In this spirit, competence is the ability to generate success, satisfaction, value and excellence from the application of knowledge and know-how.

The Business Dictionary [2] defines competence as a cluster of related abilities, commitments, knowledge and skills that enable a person (or an organisation) to act effectively in a job or situation. It further states that competence indicates sufficiency of knowledge and skills that enable someone to act in a wide variety of situations. Because each level of responsibility has its own requirements, competence can occur in any period of a person's life or at any stage of his or her career. With reference to the legal profession, the dictionary defines competence as the capacity of a person to understand a situation and to act reasonably. The disputes regarding the competence of an individual are settled by a judge and not by a professional (such as a doctor or a psychiatrist) although the judge may seek expert opinion before delivering at a judgment.

In the context of UK's Managing Health and Safety in Construction (CDM Regulations) [3], the Health and Safety Executive (HSE) elaborates on the necessity for competence as follows:

To be competent an organisation or individual must have:

1. Sufficient knowledge of the tasks to be undertaken and the risks involved

2. The experience and ability to carry out their duties in relation to the project, to recognise their limitations and take appropriate action to prevent harm to those carrying out construction work or those affected by the work

The HSE further maintains that competence develops over time. Individuals develop their competence through a mix of initial training, on-the-job learning, instruction, assessment and formal qualification. In the early stages of training and experience, individuals should be closely supervised. As competence develops, the need for direct supervision should be reduced. If you are engaging a person or organisation to carry out construction work for you, then you need to make a reasonable judgement of their competence based on evidence. The evidence will usually be supplied to you by the person or organisation quoting or bidding for the work. There are many industry card schemes which can help in judging competence. However, the possession of a card by an individual is only

one indication of competence. You are expected to make efforts to establish what qualifications and experience the cardholder has.

4. Recent developments

Given the six facets of competence elaborated earlier, the acquisition, assessment, development and management of competence poses a challenge beyond the traditional education and curriculum vitae. Whilst a blend of all six facets is a prerequisite for competency and mastery in a given discipline, the significance of each is highly dependent on the context and requirements of a given domain. Whilst theoretical knowledge plays a more significant role in abstract scenarios such as research, experience of application, adaptability and creativity may become more prominent in other domains. Whichever the domain however, a systems framework for the understanding, characterisation, evaluation, development and enhancement of competence is called for. This by necessity comprises two interdependent frameworks [4], one focused on characterisation, evaluation and assessment and the other on the management of competence in a given context.

The matters of competence and relevance of the deployed human resource to the requirements of mission and safety critical tasks have always been recognised but not been explicitly formalised until recently. The European Standard for Safety Critical Software [5, 11, 12] in the rail sector is potentially the first to recognise and formalise human competence requirements in the context of high-integrity software development for railway applications. The tables in Annex B of the standard have 10 normative role specifications in the development of high-integrity software for safety applications as follows:

B.1: Software Requirements Manager

B.2: Software Designer

B.3: Software Implementer

B.4: Software Tester

B.5: Software Verifier

B.6: Software Integrator

B.7: Software Validator

B.8: Software Assessor

B.9: Software Project Manager

B.10: Software Configuration Manager

For each one of the above roles, a template based on the UML class for the role is developed to describe the minimum competence requirements in terms of attributes (qualities) and operations (key activities and responsibilities) in the development and deployment of safety critical software. Whilst these appear simplistic and potentially inadequate, the significance of recognising and incorporating human characteristics in a traditionally process only standard [5, 11] cannot be over-stated. In this respect, the competence requirements in the safety critical software standard are just a start and a foundation for more elaborations!

In principle, many of the normative software roles are generic and can be modified and applied to hardware, subsystem and system aspects. In a complex and safety critical project, it is beneficial if not necessary to adopt a systematic approach

to characterising, assessing and managing competence in the key roles since, as a minimum, these will be required for subsystem- and system-level software developers where a fair proportion of the change will originate from. To this end, a Competence Assessment and Management System (CAMS) is an essential aspect of a credible strategy within the context of a safety critical programme.

5. Compliance versus competence: balance

What counts as competence can vary between organisations because of the balance required between the need for competence and the observation of, and compliance to, the rules/standards or processes. If the supplier's competence management system (CMS) differs to that of the client's, then delays in demonstrating acceptability of the supplier's CMS can occur. It is pertinent to note that the delivery organisation and client's individual competencies may differ due to differences in the tasks to be performed.

No two projects are the same, and where it is important to use the company's standard governance, safety management system (SMS) [13, 14, 16] and associated CMS, it is vital that each is reviewed and potentially adapted/tailored for each new project. The project documentation will declare which aspects of the governance systems are to be used (smaller projects do not necessarily require all aspects—some skill sets may need to be enhanced to meet specific requirements of a project).

The delivery scope of supply of the new ventures must be mapped in detail for the lifecycle of a project. The project organisation needs to align with the project hierarchical structure to ensure that the project can be delivered through all phases. The project competence management plan should also be reviewed to take account of any new contractual requirements (client standards, local legislation, task-based and/or functional environment, etc.) that can impact on competency requirements.

Roles and responsibilities for each post within a project organisation have to be defined (iterative process based on tasks to be performed) with defined departmental boundaries.

The competency desired proficiency level matrix (technical, time-related experience, behavioural and task-based) skills per role needs to be reviewed for each project to ensure suitability. The delivery scope of supply of a new venture must be mapped in detail for the lifecycle of the project.

The project competency management plan should be developed/reviewed to take account of any new contractual requirements (client standards, local legislation, task-based and/or functional environment, etc.); any can impact on competency requirements. Roles and responsibilities for each post within the project organisation have to be defined (iterative process based on tasks to be performed) with defined departmental boundaries. The competency desired proficiency level matrix (technical, time-related experience, behavioural and task-based) skills per role needs to be reviewed for each project to ensure suitability and best fit.

6. Competence assessment and management: a systems approach

Given the six facets of competence elaborated earlier, the acquisition, assessment, development and management of competence pose a challenge beyond the traditional education and curriculum vitae. Whilst a blend of all six facets is a prerequisite for competency and mastery in a given discipline, the significance of each is highly dependent on the context and requirements of a given domain. Whilst

theoretical knowledge plays a more significant role in abstract scenarios, experience of application, adaptability and creativity may become more prominent in other domains. Whatever the domain however, a systems framework for the evaluation, development and enhancement of competence is called for. This by necessity comprises two interdependent frameworks, one focused on evaluation and assessment and the other on the management of competence.

6.1 Assessment of competence

The competence assessment framework provides an integrated perspective on competence in a given context whilst additionally empowering the duty holders or the organisation to benchmark each aspect, measure, assess and where necessary take actions to enhance various elements in the framework. This is illustrated in the Weighted Factors Analysis [6] (WeFA) schema of **Figure 1**. The latter aspects of benchmarking, evaluating, assessing and potentially enhancing competence are inherent in the underpinning WeFA methodology [7] and not elaborated here. The schema details are omitted and elaborated in the subsequent section.

The determination, benchmarking, evaluation and quantified performance assessment of six drivers and three inhibitor goals in the above WeFA schema is carried out as follows.

6.1.1 Driver goals

The requisite "domain knowledge and understanding" in a given context as depicted in the driver Goal 1 (G1) is broadly supported by relevant industry's skill/competence frameworks. There are a number of such frameworks in use largely within various engineering disciplines in the United Kingdom, for example, OSCEng [8], IRSE [9] and IET [10]. Given the poor state of attention to competence and systematic approaches to its recognition, evaluation and assessment internationally, United Kingdom appears amongst the leading proponents globally.

The composition and extent of "skill and relevant experience" in a given context as depicted in the driver Goal 2 (G2) in the assessment framework is supported by subsequent decomposition of G2 into lower-level WeFA structures, the so-called level 2 and level 3 goals. This principally helps determine the driver and inhibitor goals for the higher-level goal, the domain experience.

The requisite "psychophysical factors and behaviours" in a given context as depicted in the driver Goal 3 (G3) in the framework is supported by subsequent decomposition of G3 into lower-level WeFA structures in WeFA. This principally

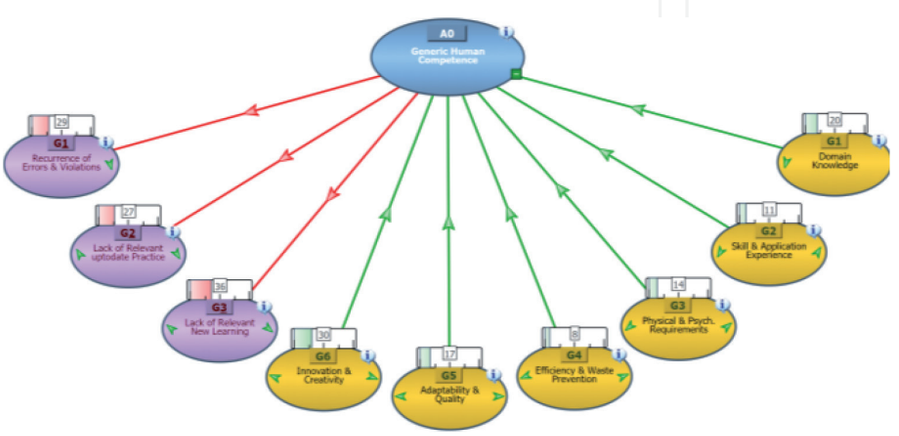


Figure 1.
The systemic competence assessment framework.

helps determine the driver and inhibitor goals for motivational, behavioural and drive aspects.

The essential determinants of "efficiency and waste minimisation" in carrying out tasks in a given context as depicted in the driver Goal 4 (G4) in the framework is supported by subsequent decomposition of G4 into lower-level WeFA structures that drive or inhibit this goal.

The key determinants of "quality, excellence and consistency" in carrying out tasks in a given context as depicted in the driver Goal 5 (G5) in the framework is supported by subsequent decomposition of G5 into lower-level WeFA structures, drivers and inhibitors, respectively.

Finally, the degree of "adaptability, innovation and creativity" in a given context as depicted in the driver Goal 6 (G6) in the framework is supported by subsequent decomposition of G5 into lower-level factors relevant to this focus.

Given the hierarchical nature of WeFA schema, the so-called level 1 goals in the proposed individual competence assurance system are generic and universal. The decomposition of these goals into appropriate drivers and inhibitors in levels 2 and beyond will help tailor the generic model towards specific requirements of a given role in a given context. The driver and inhibitor goals in levels 2 and below in a competence role schema denote the specific measurable predictors for generic level 1 goals such as knowledge, experience, etc.

Once a role is completely characterised through decomposition of the generic model (level 1) into a number of predictors (levels 2 and below), the schema is subsequently weighted by the same expert panel that have helped with the development of the schema. This assigns relative significance to the factors in the schema, thus rendering it compatible with the values, preferences and possibly culturally driven norms within the application environment. A calibrated schema is then reviewed, enhanced and validated for general application within the context of use. In an automated environment, a validated/authorised schema can be assigned to every member of staff in a given role, enabling them to evaluate themselves against the criteria and develop a competence profile to establish the areas in need of further development.

6.1.2 Inhibitor goals

The key aspects and the extent of "lack or inadequacy of relevant new learning" in a given context of application as depicted in the inhibitor Goal 1 (G1) in the proposed framework are supported by subsequent decomposition of G1 into lower-level WeFA structures, the so-called level 2 and level 3 drivers and inhibitors in WeFA.

The key predictors and the extent of the "absence or inadequacy of relevant practice" in a given context as depicted in the inhibitor Goal 2 (G2) in the framework are supported by subsequent decomposition of G2 into lower-level WeFA structures.

Finally, the degree of "recurrent errors and violations" in a given context as depicted in the inhibitor Goal 3 (G3) in the framework is supported by subsequent decomposition of G3 into specific predictors of these behaviours and outcomes in the schema.

A suitably developed and validated WeFA schema for competence assessment in a given role, context and/or domain additionally requires a measurement scale for each goal (driver or inhibitor) as well the weights, i.e. the strengths of influence(s) from each goal on higher-level goals. Once established, the weighted framework lends itself to application for assessment and management of individual's or groups' competence in fulfilling tasks in the particular context as depicted by

the framework. This would render a number of advanced features and benefits, namely:

- Up to five levels of competence typically comprising apprentice, technician, practitioner, expert and leader in a given role/domain
- Identification of the gaps and training/experience/mentoring requirements
- A consistent and systematic regime for continual assessment and enhancement

It should be noted that assessment here is devised and intended as a tool in the service of systematic approach to staff capability/talent development and should not be misconstrued as an adversarial instrument for classification of people in an organisation.

6.2 Management of competence

The deliverables of the engineering process applied to the creation and realisation of parts, products, systems or processes often follow a life cycle from concept to decommissioning as popularised by engineering standards typically comprising as follows:

1. Concept and feasibility
2. Specification and design
3. Development
4. Commissioning
5. Deployment and operation
6. Maintenance and retrofit
7. Decommissioning

In this spirit, the human resource involvement/employment within an engineering environment, organisation or project likewise follows a life cycle comprising seven key phases essential to the systematic and focused management of knowledge, namely:

1. Proactivity: comprises corporate policy, leadership, mission, objectives, planning, quality assurance and commitments to competency and service delivery for the whole organisation;
2. Architecting and profiling: comprises specification and development of a corporate structure aligned with the strategy and policy objectives together with the definition of roles and capabilities to fulfil these;
3. Placement: essentially involves advertising and attracting candidates matching the role profiles/requirements involving search, selection and induction. Selection relates to deriving role-focused criteria and relevant tests to assist with the systematic assessment, scoring and appointment tasks. Induction involves

a period of briefing, familiarisation and possibly training, the extent of which is determined by the familiarity and competence of the individual concerned and the complexity and novelty of the role;

4. Deployment and empowerment: involves a holistic description depicting the scope of the responsibility, accountability and technical/managerial tasks associated with a specific role and empowering the individual to fulfil the demands of the role. This would include training, supervision, coaching, resourcing, delineation of requisite authority and accountabilities, mentoring and potential certification as means to empowerment for achievement and development.

5. Appraisal: involves the planning and setting performance objectives and identification of the performance indicators/predictors synergistic to the demands of a role and the individual's domain knowledge, aimed at ensuring all relevant and periphery aspects of the role are adequately addressed and the necessary provisions are made for learning where a need is identified. The evaluation and appraisal provide the necessary feedback on compliance with individual and organisational objectives and achievement, enabling the organisation to identify and reward good performance and develop remedial solutions where necessary.

6. Organisation and culture: involves clarification of role relationships and communications, support, reward and motivational aspects for competency development including requisite resources and learning processes for attaining the policy objectives. This is intended to develop and foster a caring and sensitive approach/culture nurturing talents and paving the way towards an innovating organisation.

7. Continual development and progression: this comprises identifying the synergistic aspects which may serve as a complementary and rewarding extension to individuals'/teams' specific roles. Development may involve managerial, technical and support functions or an appropriate blend of duties at the whole life cycle level or extensions to the role-specific activities and vision/ career paths above an existing role into other parts of an organisation and even beyond. The review and assessment of success in all the principles inherent in the framework also fall within the continual development principle.

The seven focal areas/principles constitute a systematic competency management framework. It is worth noting however that employment and project/product

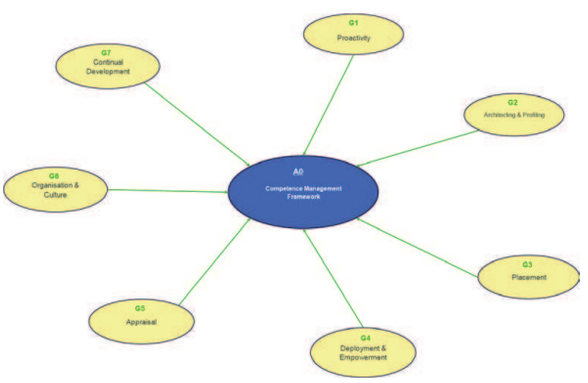


Figure 2.
The systemic competence management framework.

life cycles are orthogonal in that securing the requisite human resource and competence for any phase of an engineering production activity would potentially involve all the seven phases of the competence management.

The systematic framework for management of competence is depicted in the WeFA schema of **Figure 2**. Note that the two frameworks for assessment and management of competence are interrelated and complementary. Whilst assessment focuses on the individual and/or the team in terms of performance, the management framework addresses broader issues relating to the corporate's policy and a nurturing environment to foster competency development, [15] talent and innovation as an embedded culture, thus creating a sustainable business/service provision.

7. Competence: the way forward

The traditional process-based prescriptive rules and standards [5] have served the industry over a century where product and system complexities were generally low permitting good design and sufficient testing to ensure integrity of products, processes and systems. The pervasive complexities arising from adoption of new ICT technologies have necessitated a continuous approach to assurance throughout the life cycle as advocated by modern standards. This is now the accepted norm in most safety and mission critical applications and industries.

Alas, the significance and role of the human agent has been largely ignored so far on the unfounded assumption that a recipe given to any capable and qualified person will ensure quality and integrity of the outcomes. With the ever-increasing embedded knowledge contents in most products, processes and systems, the necessity to focus on the source of such knowledge creation, the humans, and their fitness for the task in hand is now gaining momentum. In the face of such realisation and demands, our capacity to understand, characterise and evaluate human capabilities and latent potential has lagged significantly behind other technological advances.

We posit that human competence should be regarded as an integral facet of assuring designs, products and services especially those with safety, security, sustainability or mission critical profile [17, 18]. The continual assurance processes advocated by modern standards need to complemented with focus on human competence to face the modern challenges of high risks and ever-increasing complexity. The framework offered uses systems thinking to address assessment and management of competence within a coherent solution for enhancing quality, safety and reliability and assuring integrity.

Acknowledgements

Contributions from Andy Mallendar in the discussions and some facets of this introductory chapter are hereby gratefully acknowledged.

DOI: http://dx.doi.org/10.5772/intechopen.90260

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Author details

Ali G. Hessami
Innovation Director, Vega Systems, London, UK

*Address all correspondence to: hessami@vegaglobalsystems.com

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