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ARTICLE

Towards the integration of organisational culture models into model-based systems engineering approaches for enterprise systems transformation

G.A.L. Kennedy, F. Shirvani, W. Scott and A.P. Campbell

SMART Infrastructure Facility, University of Wollongong, Wollongong, Australia

ABSTRACT
Enterprise systems modelling requires integrated views of both technical systems as well as organisational systems that together will deliver the anticipated capabilities. A major challenge in such modelling is the expression of 'soft' or human aspects of the organisation where measures seem intangible, behaviour unpredictable or constrained to ad-hoc, qualitative assessment. In particular, although most businesses are concerned with managing organisational culture, how can these cultures be modelled in a manner that enables it to be integrated with the holistic enterprise system model in order to drive assessments and yield insight for managers? Initial modelling efforts showed that many aspects of organisational culture could be modelled and integrated successfully within wider enterprise systems modelling. This paper describes a Model-Based Systems Engineering approach to the development of organisational culture models and demonstrates how changes made to the integrated enterprise model may yield insight into how organisational culture will need to evolve as enterprise systems transform.

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Model-based systems engineering; organisational culture; enterprise systems transformation

1. Introduction

Organisational Culture is described as 'a pattern of shared basic assumptions that the group learned as it solved its problems of external adaptation and internal integration, that has worked well enough to be considered valid and, therefore, to be taught to new members as the correct way you perceive, think, and feel in relation to those problems' (Schein 2010). Put simply, organisational culture is the shared values that glue an organisation together and distinguish that organisation from others. Culture is often viewed as an intangible factor; it can be both something that evolves from the aggregation of individuals and shared experiences, but can also be shaped through individuals member's immersion in teams, rewards and leadership (RSSB 2008).

There is no consensus within the research community over a definition of, or indeed the facets of organisational culture, this is partly due to the differing viewpoints of the researchers, and variability in how the facets are 'cut'. Management and governance perspectives seek to look at how organisational culture is linked to organisational improvement and ultimately performance, and how to assure this (Rasman 2017). The organisational behaviour and organisational theory fields seek to understand how organisational cultures form and how they affect the behaviour of the organisation as a whole (Hatch and Cunliffe 2006; Robbins and Judge 2007). This also overlaps with the cognitive or inward views of culture that provide insight into how individual's beliefs, values and perceptions are manifested in organisations (Schein 1992). The risk and safety perspectives seek to understand how the organisational culture both supports safety or creates risk and links safety culture to safety performance. The Occupational Health and Safety field has an outward view of culture that identifies the characteristics of organisations that focus on safety and leadership rather than how culture is categorised at all (Borys 2014). Within all this, there are different types and applications of culture (e.g. safety culture, open culture, innovative culture, corporate culture, national culture, ethical culture, etc.). For the purposes of this paper, the different types of culture are considered under the umbrella of organisational culture.

The University of Wollongong (UOW) has developed a tool named the Organisational Capability Maturity Model (OCMM) through funding and support from the Australasian Centre for Rail Innovation (ACRI). The OCMM is a Model-Based Systems Engineering (MBSE) tool that enables organisations to develop integrated, holistic models and analyses to provide insight into the Human Factors (HF) and organisational considerations when new technologies are introduced. Two case studies with Australian heavy rail operators were used as a vehicle to demonstrate how the models could be tailored to different organisations. While this paper focuses on the development of one part of the OCMM concerned with Culture Manager, Table 1 shows the

CONTACT G.A.L. Kennedy gracek@uow.edu.au

Table 1.: OCMM scope.

User portals	Processes	Technologies
• Track Worker • Competency Manager • Training Manager • Safety Assurance • Workforce Manager • Role Modelling • Resourcing • Workload • Situational Awareness • Cybersecurity Manager • Culture Manager	• Track Work Procedures • Train Operation • Train Control • Drone Operation • Overhead Wire Inspection • Customer Information Management	• European Train Control System (ETCS) • Drones • Tablets • Customer Information Management Systems (CIMS) • Advanced Train Management Systems (ATMS) • Enterprise Asset Management (EAM) • Data Storage Cloud • Customer Interactions

full scope of the OCMM and further detail on the tool development can be found in (Shirvani et al. 2019). As new technologies are adopted that will affect the design, structure and communication of teams, it will be important to consider how they will support the cultural values that are required for future roles to undertake their job effectively (and how it may differ from the existing cultures) to ensure that the organisation is performing as expected.

This paper first introduces how organisational culture can be managed within the context of enterprise system transformation (including technology introduction). A brief review of the literature around common existing models of organisational culture is presented, and candidate techniques for identifying and measuring organisational culture are explored. The next section discusses the need for understanding how organisational culture relates to the wider organisational issues and describes an approach to integrating organisational culture into enterprise system models. Examples from a case study application of the OCMM tool for Heavy Rail systems are provided to demonstrate the concepts. The final section concludes the paper and provides suggestions for future directions on the research.

2. Managing organisational culture in the enterprise system

The culture that binds together an organisation paradoxically causes inertia to change. Changing an organisation's culture is a complex undertaking and does not tend to be fast paced. Single (non-holistic) approaches to cultural change will not yield easy wins, multi-faceted approaches are required for enduring cultural change to occur (Rasman 2017). Given that there are many facets of organisational culture (perspectives, taxonomies and types) used for different purposes, how can organisational culture be modelled within the context of the enterprise system under transformation? A flexible framework is required that is tailorable to a selection of these multi-faceted approaches. MBSE approaches align well to these multiple views and can provide for participatory collation and integrated analyses of diverse sources of information.

This section of the paper describes approaches for how organisational culture and enterprise transformation can be managed. There are four0F[1] main areas involved in the good practice of managing organisational culture (Rasman 2017):

1.Identifying culture
2.Setting culture
3.Embedding culture
4.Gaining assurance over risk culture

Figure 1 depicts the concepts of managing organisational culture framed by the evolution of the organisation as the enterprise transforms. An enterprise system exists within an ecosystem; changes within this ecosystem will stimulate the need for change. Large shifts in the macro-environmental factors (e.g. Political, Economic, Social, Technological, Legislative or Environmental) or changing boundaries and interactions between constituent enterprises systems in a wider System of Systems (SoS) (or extended enterprise) would cause the enterprise system of interest to adapt to remain viable. In turn, the organisations within the enterprise system must evolve in order to meet the new capabilities required. The organisational change is depicted in Figure 1 as a helical conveyor, in this case the iterative management of the culture is driving this evolution. This figure just shows one aspect of the organisational system, culture, realistically there would be many other aspects (e.g. competency, training, organisational structure, roles, strategy, etc.) on the conveyor threads that need to work in sync along the 'organisation' axis to enact the overall change. Although organisational change may appear continuous, it is not feasible, nor time and labour efficient to model every detailed shift and change that can occur in the ecosystem. Businesses will need to carefully select a set of discrete events that will be analysed. Consideration should be made of the extent of the envisaged change and possible impact on the enterprise. Purchase et al. (2011) suggest that there are three candidate criteria for distinguishing such transformations:

1.Response to radical changes in the environment
2.Fundamental alteration of context
3.Step change in performance

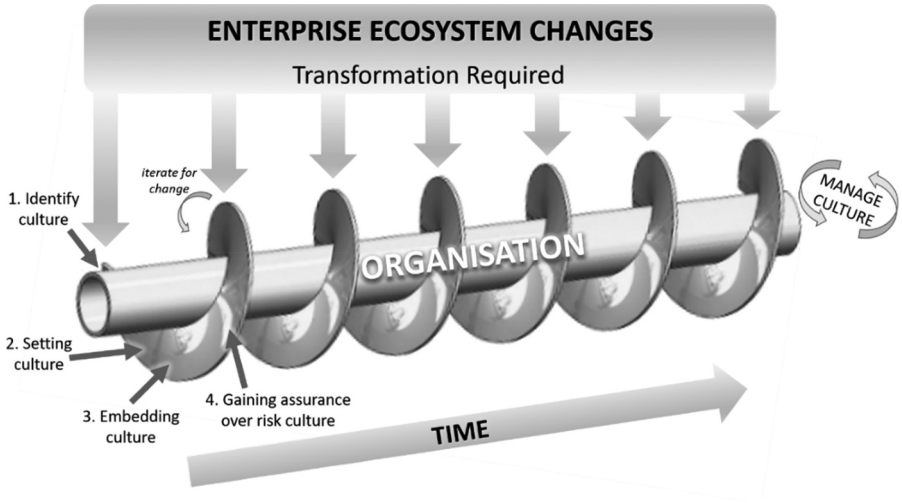

Figure 1. Managing the culture of the evolving organisational system.

3. Modelling organisational culture

As described in the introduction, there are numerous views that form the basis of different models of organisational culture. There is extensive research into summarising and comparison of the contemporary literature on organisational culture and the varying 'camps' of research that currently exist (Cacciattolo 2014; Hatch and Cunliffe 2006). Table 2 summarises commonly used models of organisational culture that were considered within this research. For simplicity, the main elements or constructs are provided, any relationships between elements are not presented in this paper due to brevity (however further details of the models may be found via the citations).

Table 2 shows the variability in organisational culture models. Some models build upon others (e.g. Hatch and Cunliffe (2006) and Schein (1992)), whilst others display some degree of overlap with others (e.g. Hofstede (1984) and Cameron and Quinn (2011), and others take a different viewpoint leading to other sets of categories/levels. For the purposes of the OCMM development, these models of organisational culture were loosely grouped into three types (models may fit into one or more of these groupings):

1.Models involving how cultures are realised (this includes both cognitive and behavioural theories)

2. Models involving how cultures can be characterised

3.Models that look at a broader picture involving the internal environment (scoped to the organisational or enterprise level) or further still to the external environment (scoped to the enterprise's ecosystem level)

Models are created as representations or abstractions of a real-life situation to provide insight into or answer questions about the model structure or behaviour that may be expected under different conditions. MBSE approaches enable modellers to consider different types of overlapping models contained within an overarching framework. As different businesses would use different type 1 or 2 models of culture, any tool would need to be flexible to accommodate those types of elements. As the OCMM contains sets of models of

Table 2. Models of organisational culture.

Organisational Culture Model	Model Developer	Culture Categories/Levels
Three Level Framework	(Schein 1992)	Artefacts (visible behaviour); Espoused values (rules, standards); Basic underlying assumptions (invisible, unconscious)
Model of National Culture	(Hofstede 1984)	Power distance; Collectivism – Individualism; Femininity – Masculinity; Uncertainty avoidance; Short term – Long-term orientation; Restraint – Indulgence
Four Power Structures	(Handy 1993)	Power culture; Role culture; Task culture; Person culture
Theory of Basic Values	(Schwartz 2012)	Self-Direction; Stimulation; Hedonism; Achievement; Power Security; Conformity; Tradition; Benevolence; Universalism
Primary Characteristics of Organisational Culture	(Robbins and Judge 2007)	Innovation and risk taking; Attention to detail; Outcome orientation; People orientation; Team orientation; Aggressiveness; Stability
Cultural Dynamics	(Hatch and Cunliffe 2006)	Artefacts; Values; Assumptions; Symbols
Configuration Model of Organisational Culture	(Dauber, Fink, and Yolles 2012)	Organisational Culture; Strategy; Structure; Operations; Task Environment; Legitimisation Environment
Cultural Traits	(Denison, Nieminen, and Kotrba 2014)	Involvement; Consistency; Adaptability; Mission
Competing Values Framework Quadrants	(Cameron and Quinn 2011)	Internal focus and integration – External focus Stability and control – Flexibility and discretion

the enterprise system (both system and organisational models), this is more closely aligned to the type 3 models. Any model of organisational culture would need to reuse (and be reused by) other elements in other parts of the enterprise model.

Schein's three level framework of organisational culture (Schein 2010) is a commonly used type 1 model, these levels are given as:

1.**Artefacts (How things and people appear)** – these are both the physical and behavioural manifestations that may be observed within an organisation.

2.**Values (What people say and think they believe)** – the second factor involves individual's perception of the values of the organisation.

3.**Assumptions (What people really think and believe)** – these are the values of the organisation that are more intangible, they are held within individuals, they are the unspoken rules.

For OCMM, levels 1 and 2 are considered (level 3 would require intensive survey and assessment of individuals). The OCMM contains various models of the organisational structures, roles, and processes, which share elements with the organisational culture models.

4. Assessment of organisational culture

Surveys have been used as instruments to measure aspects of organisational culture based on the models introduced in the previous sub-section have been developed over the last thirty years (Denison, Nieminen, and Kotrba 2014) to provide businesses with discrete data on the identification of culture within organisations and individuals. Revisiting Rasman's areas of good organisational culture management (Rasman 2017), it is evident that assessment is essential throughout the management process. For each area it is important to consider the following question: *Are the right things being assessed and are they being assessed correctly?*

1.Identify culture – Assess the current culture.

2.Setting culture – Decide on the desired organisational culture.

3.Embedding culture – Assess how the organisational culture is reflected in the strategy and how it will be embedded and governed, then assess how well the culture is being embedded and maintained.

4.Gaining assurance – Assess whether the current culture meets the desired culture and areas to target where alignment can be improved.

One of the most common assessments is the Organisational Culture Assessment Instrument (OCAI) which is based on the Competing Values Framework (Cameron and Quinn 2011). The OCAI is used to 'diagnose' an organisation's culture in order to predict organisational performance. A two-step process is used to identify the current organisational culture, and then identify how the organisations thinks it needs to be to meet future demands (matching Rasman's areas 1 and 2 above). The OCAI provides a set of survey statements, grouped into the six items (dominant characteristics, organisational leadership, management of employees, organisation glue, strategic emphases, and criteria of success) that ask individuals in the organisation to weight the importance of each statement against the 'now' and the 'preferred' state. The pros of this assessment technique are that it is quick to use (should take no more than 10 minutes to complete the survey) and easy to understand. The cons of this technique are that there may be large amounts of data which are based on 'opinion', careful selection of individuals would be key to getting a fair and representative view on the current culture, this also applies to finding individuals who know enough about the decisions about the future of the organisation, and breadth of knowledge to have the ability to know what a 'preferred' state should actually be.

Other forms of assessment use an ideal set of characteristics of best practice as the goal to aspire to and measure the organisational culture against levels of maturity towards the goal state. This is particularly the case for the safety discipline. The Hudson (2007) Safety Culture Ladder is one such maturity model that has gained traction in a variety of industries. The ladder is composed of five sequential 'rungs' that describe the state of an organisation's safety culture. The theory is that organisations meeting the characteristics for each rung, should then develop a road map towards the next rung to improve and maintain the change. This maturity model covers all four of Rasman's areas. The pros of Hudson's approach are that it gives businesses proactive goals and helps to initiate the types of changes to be made. A set of tools were developed alongside the models to prescribe the activities to enact the changes and embed them within an organisation. In a similar fashion to OCAI, the tools enable individuals and groups to assess themselves and others using ratings against descriptors about attitude and behaviour. The tools are used mostly from a bottom-up perspective to enact change from the roots, this can be a difficult mindset (especially in safety critical industries) where stronger top down governance is common and authority less likely to be delegated downwards in an organisation.

Where safety culture has definite safe and unsafe behaviours, and organisational characteristics to aspire to, organisational culture in general is more dependent on the individual circumstances and context for each organisation (or sub-organisation) and the required future state of the organisational culture may vary from team to team (depending on their goals and the nature of the teams) as well as globally to the organisation. Clayton, Kennedy, and Siemieniuch

(2007) describe a Soft Factors Modelling Tool (SFMT) that surveys at individual, team and organisational level to identify the current cultural value pairings (based on various dimensions of culture from literature), but develops the 'ideal' culture by mapping a set of likely types of tasks and systems environment context against the cultural value pairings that would be more likely to be inhibitive or supportive of a goal or mission scenario. The SFMT was developed to support decision-making in terms of dynamic selection of socio-technical teams or units for different missions or provide insight into possible cultural value clashes. Whilst the tool provides contextual future states, it was not designed to show how to improve or change the organisational culture.

The final organisational culture assessment covered in this paper concerns a specific tool being used within the Australian rail industry. The Rail Industry Safety Standards Board's (RISSB) Organisational Culture Work Health and Safety (OCWHaS) survey has derived a set of 40 questions (Baker 2018; Clarkson et al. 2014) based on the '10 Platinum Rules for Good Organisational Culture' (Shaw et al. 2007). Each of the ten rules are broken down further into descriptors and mapped across to a set of questions for survey. The survey has been specifically tailored to the Australian rail industry and is available as an online survey for individuals and an analysis tool for RISSB members. Results can be benchmarked against the data trends across all the participants from different rail businesses.

This section has provided a brief overview of some contrasting models and techniques that are being used to assess organisational culture. Each have pros and cons, and are fit for purpose for different organisations and applications. The OCMM is intended to be flexible for businesses to integrate any of the elements (from any model(s) of organisational culture) that the business has decided upon, using whichever assessment techniques that are deemed fit for purpose. The OCMM tool contains a library of cultural values that contain some of the common dimensions or characteristics of culture. The case studies described later in this paper focus on the OCWHaS groupings, but also adds specific values identified by the participant organisations in addition to the different aspects or dimensions from literature (as described above).

5. Integrating organisational culture into enterprise system modelling

The field of organisational culture research is relatively young, and although there have been many seminal works in defining models of, identifying and assessing organisational culture (as described in the previous section), there is a gap in the research that identifies how organisational culture changes over time as other organisational elements evolve (Dauber, Fink, and Yolles 2012). Rather than trying to change culture in a standalone fashion, the research agrees that culture needs to be driven and viewed from the perspective of organisational change (Rasman 2017). The Burke-Litwin model for Organisational Change (Burke 2017) identifies culture as one of the twelve key drivers of change for organisations, and warns of the dangers of not considering how these different drivers influence each other.

Organisational culture is just one aspect (or construct) of an organisational system. In order to assess culture effectively it is imperative that the enterprise system is considered in a holistic and integrated manner (Kennedy, Siemieniuch, and Sinclair 2007) and not singling out any one construct such as culture in a standalone fashion without consideration of the other constructs. The interrelationships between culture and other constructs of the organisation's behaviour must be explored, both internally (e.g. culture to competency or strategy) and externally (e.g. the interactions with macro-economic factors or other organisations) (Burke 2017; Dauber, Fink, and Yolles 2012). As described earlier, organisations evolve and are in a state of flux, in a similar fashion, the organisational culture will also be evolving within the system over time.

MBSE is used to shield the complexity of the enterprise system model by providing views from different stakeholder's (of the tool) that present and manage the models and information pertinent to that user. The tool uses an enhanced Unified Architecture Framework (UAF) (OMG 2017) that specifically integrates the constructs of organisational system models within the context of the enterprise system. Shirvani et al. (2019) describe the technical MBSE architecture framework development of the OCMM in further detail. Figure 2 shows an excerpt of the parts of the OCMM metamodel concerned with organisational culture. The full metamodel would be too big and complicated to be shown effectively on the page. The key constructs are shown, with the associations (or relationships) between the elements. The metamodel only contains the empty constructs of organisational culture, this means that it is agnostic to any particular organisational culture model or assessment technique, it is by no means exhaustive of all possible constructs and relationships for all possible theories to be modelled, but is expansible through the use of profile diagrams to create new stereotype constructs. The constructs given here cover a breadth of concepts from the literature. The culture libraries are used to enter or import sets of concepts or information that will be used in the organisational culture models.

The OCMM metamodel is used as the 'building blocks' for specific models of an enterprise system of interest. The intention is that organisational models

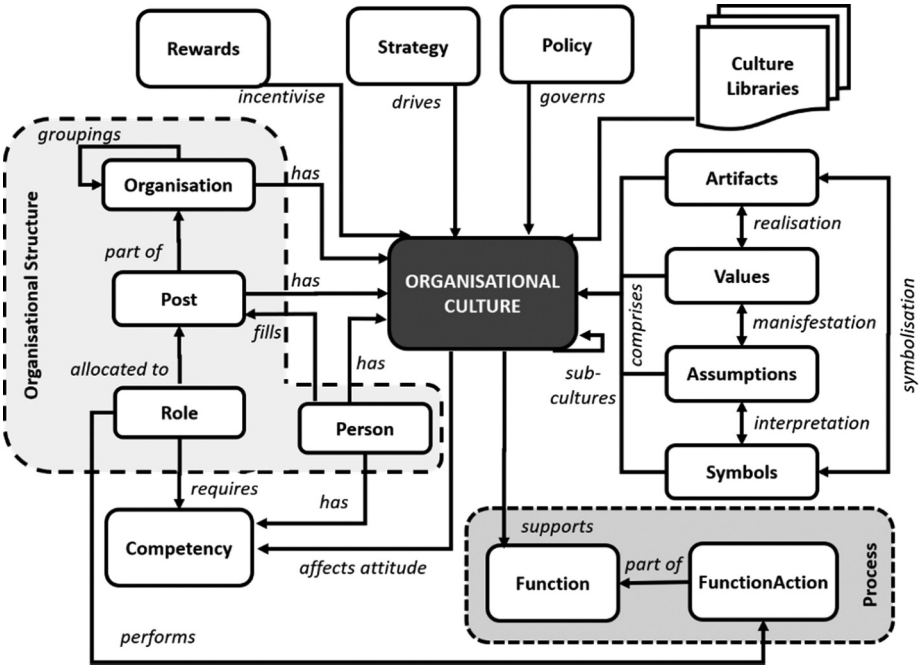

Figure 2. OCMM organisational culture metamodel.

are developed at each planned transformation point (Figure 1), and that these models can be used to assess for improvement in the current organisation as well as for comparison against organisational models of a future state to plan the change.

As ascertained in the literature presented thus far in the paper, managing the organisational culture within the context of integrated enterprise systems transformation is challenging, and simply creating an integrated model is not the end goal. Models must be developed for some purpose in order to bring insight into problems. To do this, the stakeholder or actor who owns the problem (in this case the 'Culture Manager') has a number of use cases that will drive their requirements for a modelling support tool. Figure 3 shows the envisaged use cases. The group of use cases to the left (bounded by the dashed rectangle) show the use cases for managing culture (as identified by Rasman (2017)). The use cases to the right of the diagram (in hub formation) involve the Culture Manager gaining understanding of the planned transformation from a number of different views of the enterprise system, this aligns with the areas covered within the metamodel in Figure 2. The Culture Manager will require access to models of the enterprise system that are 'owned' by managers of other viewpoints (and vice versa). It is not the case that the Culture Manager waits to receive a fully developed transformation plan. Each manager (see Table 1) is working together and liaising to mature the models of the enterprise system; each providing input, feedback and trade-

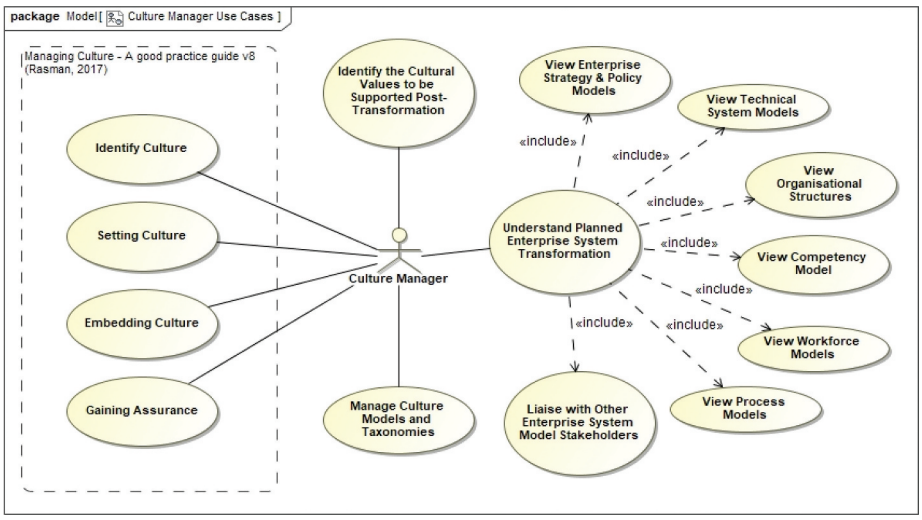

Figure 3. Culture manager use cases.

offs from their perspective, whilst evolving their understanding of the transformation and adjusting their management plans accordingly (from the Culture Manager viewpoint this understanding will be used to develop models of culture for future states of transition).

6. Case study: Australian heavy rail

This section provides examples of the OCCM tool's functionality (with respect to organisational culture). The Culture Manager part of the tool does not contain full development of all of the possible use cases identified in Figure 3, but was designed to contain a subset of use cases that would enable aspects of the culture models to be integrated into MBSE activities. The models are at the exploratory stage and are intended to be used alongside existing enterprise models to add extra layers of insight into planned technology introduction. Businesses adopting such techniques should tailor the libraries and specifics of the functionality to their circumstances. The organisational models were populated using information specific for two case studies relating to two Australian Heavy Rail operators; however, the cultural survey assessments hold dummy data intended to test and demonstrate the tool capabilities. Ideally, real data from the RISSB OCWHaS survey would be imported into the tool to provide the 'as is' and appropriately qualified SMEs from the organisations would assess the current and future organisational cultures. For the case study rail operators, customer-focussed cultures are strived towards. This case study example focusses on the cultural values at the organisational, group and individual level undertaking different processes or tasks, and is scoped to the introduction of new Customer Information Management Systems (CIMS). Referring back to Figure 1, this technology introduction represents a required transformation of the enterprise system, which in turn will involve identifying the current culture and setting the future culture that will support the new technology. This would then support a Culture Manager in planning for the transformation. The tool has been developed in MagicDraw™ software primarily using SysML (OMG 2019).

The OCMM utilises stakeholder-driven development to build user portals that guide a set of users through the parts of the models that are of interest to them, whilst maintaining the consistency of information held in the underlying whole. A *Culture Manager* user portal was created to provide three main concerns that such a user would want to address when considering the impact on organisational culture:

1.Add Cultural Values – enter the libraries of information that the business wishes to use to identify and assess the organisational culture. Assess the cultural value needs for the current (pre-transformation) system.

2. Survey Cultural Values – identify, collect and store survey responses from individuals.

3.Cultures for New Technologies – using models of the enterprise system to provide context about the planned transformation, assess the future culture needs, and compare current to future culture to provide insight into how culture will need to transform.

The Culture Manager user portal presents information about the enterprise system that is needed to manage culture. The formal organisational structure models provide the decomposition of an organisation, its units, groups, teams and individuals performing different roles. Although organisations may have a preferred single-set of cultural values that are visible in a workplace, it is important to understand that different groups, undertaking different functions or with different goals, will exhibit different sets of cultural values (e.g. for a safety critical task, one would expect rule adherence to be very high, whereas a group whose function is innovation may suffer from stifled creativity if the rules are too constraining). The organisation will be able to use the output of the OCWHaS survey to assess the 'as is' group and role data against the 'ideal' to measure how well the elements of the organisation are meeting the cultural values required.

Cultural values are also modelled as a type of attitude within the attributes of competency. Competency should include the knowledge, skill and experience of an individual, but should also consider the attitude of the individual (are they likely to want to apply their capability and behave in an effective way to perform a task?). Competency requirements may be applied for tasks as well as for roles performing tasks. The Culture Manager has access to the competency libraries within OCMM to gain contextual information about the tasks and individuals involved.

The Culture Manager will need access to the pertinent information held in current and future enterprise systems models to understand what the planned transformation will look like. New tasks associated with the new technologies may be introduced which will have a set of cultural values that would support the task, other tasks may remain under transition with the nature of the task evolving, and some tasks may be defunct after transformation.

6.1. Add cultural values

The first step in setting up the data structures for the Culture Manager is to identify a library of cultural values that are applicable for the business. Figure 4 shows the activity diagram provided to guide the user. Sets of cultural values have been pre-entered into the tool from research, industry and also from information specific to the case study rail operators. These are

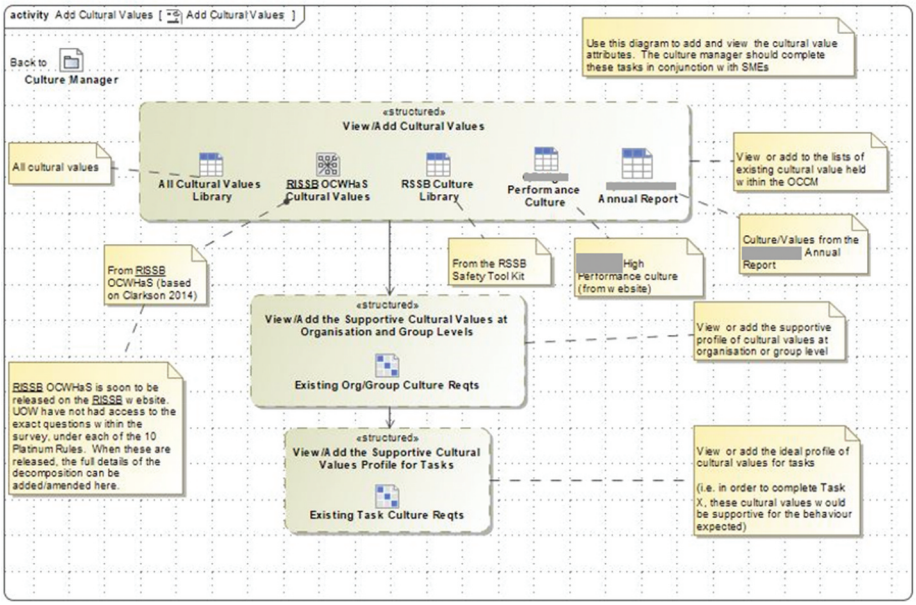

Figure 4. Add cultural values.

presented as links to the 'All Cultural Values' table which gives a master list of the contents library, as well as other links to view/add cultural values that are based on the aforementioned sets. Further sets should be added as determined by the Culture Manager.

The next step in the activity is for the Culture Manager to assign the ideal cultural values to the organisation and groups held within the organisational structure. The values can be assigned against Likert scales to discern the strength of the link (the scales used in this case study match the two scales used in the RISSB OCWHaS survey). Groupings within organisations are not homogenous in terms of culture, this table enables the manager to assess the most pertinent or important values or behaviours expected for different groupings. Figure 5 shows an example assessment with dummy data assigned at organisational and group level (SMEs or individuals representing these groups should complete this assessment by considering the cultural values most likely to support or inhibit a group's performance). The cultural values used in this case study are discussed in more detail in Kennedy et al. (2020).

The final activity in this section is for the Culture Manager is to consider the cultural values at task-level. Figure 6 shows the pertinent cultural values that would support the behaviours expected during specific tasks. The user can select any of the processes or tasks

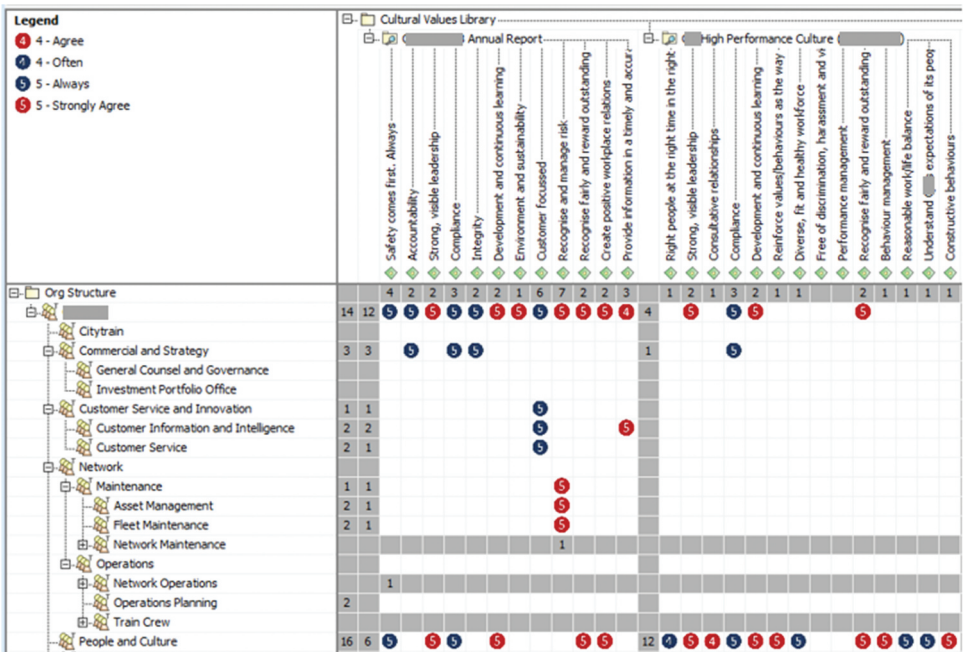

Figure 5. Cultural values at organisational and group level (excerpt).

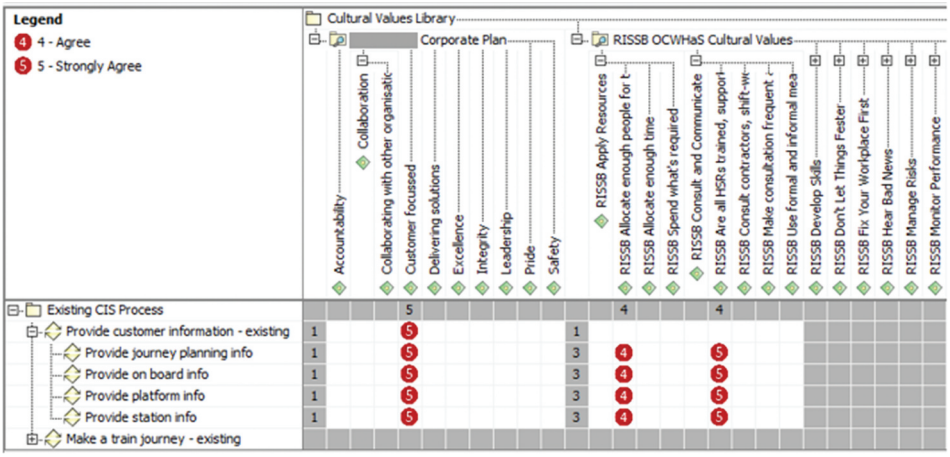

Figure 6. Map the cultural values to the existing tasks.

of interest that have been modelled elsewhere in the OCMM. In the example below, the existing *provide customer information* process is of interest, as would be expected customer focussed values are strongly supportive of this process.

6.2. Survey cultural values

The second concern block within the Culture Manager user portal is a placeholder for comparing the existing 'ideal' cultural values at group and role level to the 'as is' results of the RISSB OCWHaS. This concern was not within the scope of the current OCMM research work, so specific import requirements have not been considered; however, the data has been structured such that information from OCWHaS could be integrated in the future. Comparisons may then be made between the OCWHaS department survey results and the matching sub-organisation held within the OCMM organisational structures. The 'as is' OCWHaS roles survey results may then be compared against the 'ideal' roles' cultural values (which can be provided by mapping the tasks from Figure 6 to the roles performing that task).

6.3. Cultures for new technologies

The final concern block in the Culture Manager user portal enables the user to consider how the introduction of new technologies will impact upon the cultural values of the organisation. This is achieved by assessing how new technologies are supportive or inhibitive of the cultural values required of an organisation. Figure 7 shows the activities that guide the user in analysing the culture under the introduction of CIMS.

The first step in the analysis is to consider the existing customer information management processes and assess which cultural values (from the cultural

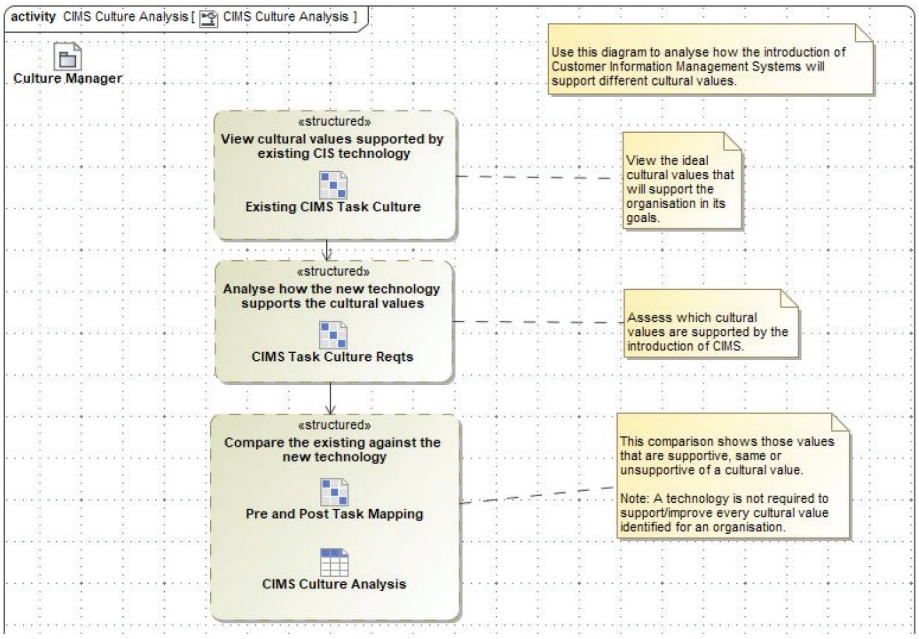

Figure 7. Culture analysis (CIMS).

values library) are supported by each process. The Culture Manager may have already done this through the 'Add Cultural Values' part of the Portal (see Figure 6). The next step is to repeat the analysis, but for the future state of the process once the new technology has been adopted. Figures 6 and 8 show a simple example for the existing and future CIMS, respectively.

The user can access system models created in other parts of the OCMM about the new technology of interest to provide context to the planned change. Figure 9 shows an example structure model of the system resources for a future CIMS.

In order to compare the pre- and post-transformation state, the Culture Manager will need to map the existing and the future processes (note that some will have a direct match, others may be defunct processes with no future process to map to, and some will be new processes that did not previously exist as a functionality). Figure 10 shows the example mapping for the existing and future CIMS processes.

The final part of the analysis presents a summary table that collates the assessments. Level 4 ('Often' or 'Agree') or Level 5 ('Always' or 'Strong Agree') is classed as a supportive level, but the sensitivity could be changed to whatever level deemed necessary by the Culture Manager (likewise, lower sensitivities could class the possible inhibitive values). Figure 11 shows the analysis for the introduction of CIMS. The analysis summarises the existing and future supportive cultural values and then auto-generates two further columns; new supportive values (highlights where new technologies are able to provide supportive values that were previously not supported) and discontinued supportive values (those that are no longer supported). The Culture Manager should use this information to spur further investigation into understanding how to evolve the culture to meet the new technology introduction. The results could also be used to compare different candidate technologies, and whether they will support the organisation to meet the strategic goals and culture it aspires to. These analyses help support

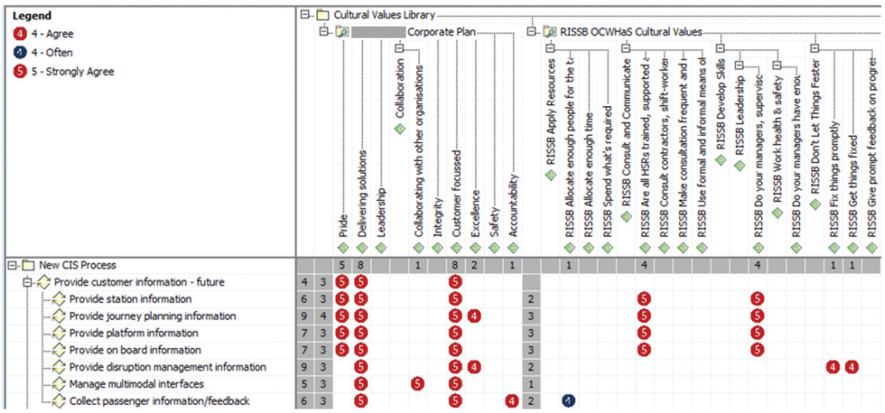

Figure 8. Assess the cultural values for the future processes (new CIMS).

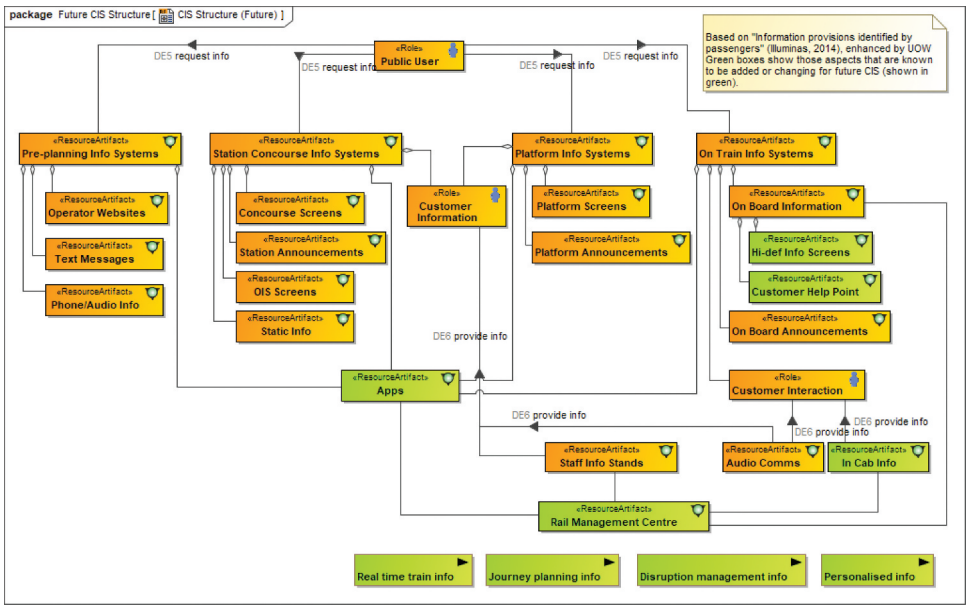

Figure 9. Future CIS structure.

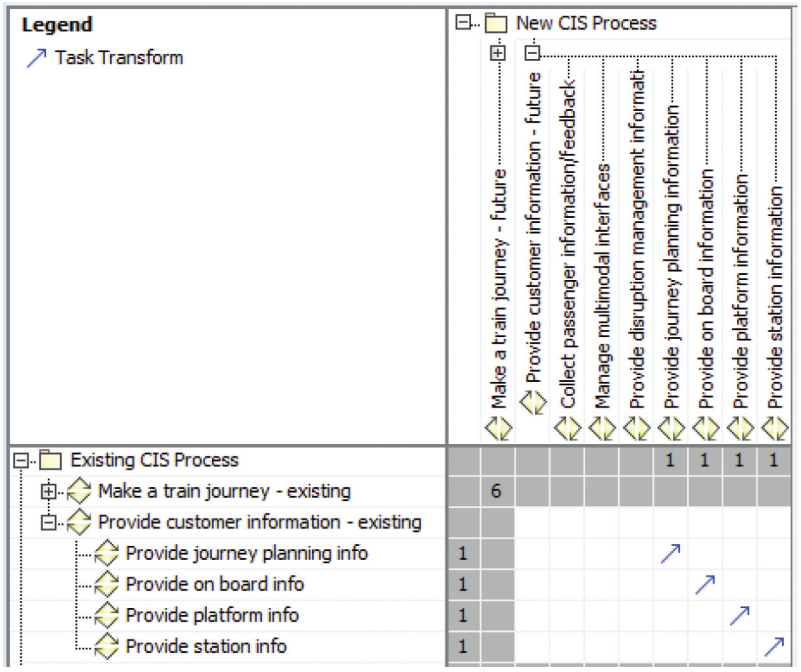

Figure 10. Mapping of pre- and post-technology introduction.

#	Name	Supported Values - Existing	Supported Values - Future	New Supported Values	Discontinued Supported Values
1	Provide customer information - future		Customer focussed People orientated Pride Delivering solutions	Customer focussed Pride Delivering solutions People orientated	
2	Manage multimodal interfaces		Customer focussed People orientated Collaborating with other organisations Delivering solutions RISSB Treat people with dignity and respect	Customer focussed RISSB Treat people with dignity and respect Delivering solutions People orientated Collaborating with other organisations	
3	Collect passenger information/feedback		Customer focussed People orientated Delivering solutions RISSB Allocate enough people for the task RISSB How do you know you're effective? Accountability	Accountability Customer focussed RISSB How do you know you're effective? RISSB Allocate enough people for the task Delivering solutions People orientated	
4	Provide station information	RISSB Are all HSRs trained, supported an RISSB Treat people with dignity and respe Customer focussed People orientated RISSB Allocate enough people for the tas	RISSB Are all HSRs trained, supported and in RISSB Do your managers, supervisors and H Customer focussed People orientated Pride Delivering solutions	Pride Delivering solutions RISSB Do your managers, supervisors and H	RISSB Treat people with dignity and respect RISSB Allocate enough people for the task
5	Provide journey planning information	RISSB Are all HSRs trained, supported an RISSB Treat people with dignity and respe Customer focussed People orientated RISSB Allocate enough people for the tas	RISSB Are all HSRs trained, supported and in RISSB Do your managers, supervisors and H Customer focussed People orientated Pride Delivering solutions RISSB Treat people with dignity and respect Specific tailoring Excellence	Specific tailoring Excellence Pride Delivering solutions RISSB Do your managers, supervisors and H	RISSB Allocate enough people for the task
6	Provide platform information	RISSB Are all HSRs trained, supported an RISSB Treat people with dignity and respe Customer focussed People orientated RISSB Allocate enough people for the tas	RISSB Are all HSRs trained, supported and in RISSB Do your managers, supervisors and H Customer focussed People orientated Pride Delivering solutions RISSB Treat people with dignity and respect	Pride Delivering solutions RISSB Do your managers, supervisors and H	RISSB Allocate enough people for the task
7	Provide disruption management informatio		Adaptability Customer focussed People orientated Responding to the environment Delivering solutions RISSB Fix things promptly RISSB Get things fixed Acceptance of new technology Excellence	Acceptance of new technology RISSB Fix things promptly Customer focussed RISSB Get things fixed Excellence Responding to the environment Adaptability Delivering solutions People orientated	
8	Provide on board information	RISSB Are all HSRs trained, supported an RISSB Treat people with dignity and respe Customer focussed People orientated RISSB Allocate enough people for the tas	RISSB Are all HSRs trained, supported and in RISSB Do your managers, supervisors and H Customer focussed People orientated Pride Delivering solutions RISSB Treat people with dignity and respect	Pride Delivering solutions RISSB Do your managers, supervisors and H	RISSB Allocate enough people for the task
9	Make a train journey - future				

Figure 11. CIMS culture analysis.

the decisions made by the Culture Manager in a traceable manner that considers various aspects of the enterprise system.

The OCMM was developed in conjunction with the rail operator participants from ACRI. Feedback from these stakeholders during demonstrations has been positive with stakeholders appreciating the benefits of the holistic view, traceability and consistency of information. At this stage, the research has explored the feasibility for a subset of models of organisational culture to be integrated with enterprise system models for transformation. The models and tool developed from this research require further validation through population with the organisation's real data and improvements to design with SMEs to improve the concepts to be fit for purpose. The paper has described

how organisational culture models and use cases for managing culture for enterprise system transformation can be considered. Future development of more complete metamodels and the full set of use cases (and user requirements) is needed to create a truly integrated tool that will enable the models and analyses created to reflect the complexity of the enterprise system.

The tool described considers enterprise system transformation due to the introduction of new technologies, further lines of enquiry should explore the nature of the organisational response to other transformative stimuli and multiple organisational changes (it is likely that any organisation in flux will be under numerous staggered and concurrent transformations).

7. Conclusions

Engineering businesses planning transformation due to the introduction of new technologies need to consider the planning, synchronisation and complexity of implementing both the technical and organisational capabilities. There are numerous research communities and extensive literature within the two fields of organisational culture and enterprise systems modelling, the intended beneficiaries of this research reside within these fields, particularly those who are also involved in MBSE and HF. Although it is clear that the fields have overlaps and are interrelated, research into harmonisation and application of such holistic models for transformation have not been equally extensive (Dauber, Fink, and Yolles 2012). This paper builds on the body of research in enterprise systems modelling by introducing how the constructs of organisational culture can be integrated with existing enterprise system models. The proposed integrated model bridges the gap to link efforts in understanding the impact of organisational culture to broader MBSE and enterprise systems modelling initiatives, enabling leveraging of value by providing additional layers of insight over existing modelling efforts and reducing duplication. The research undertaken has made a positive advancement in understanding how to integrate and apply organisational culture models within enterprise systems transformation; however, there is much more to be achieved in this area of research in order to realise the full benefits.

The case study demonstrated the concept for how an MBSE approach can be used to coordinate and manage the information within the model whilst shielding users from the complexity of the whole enterprise system model. Different types of managers or users will liaise to form a shared understanding of the future enterprise system (albeit from contrasting viewpoints) in order to integrate and mature the transformation plans. The benefit to the Culture Manager is provision of a holistic understanding of the current contextual information on the planned enterprise system as it matures, thus enabling effective and tailored change management planning. Analysis of the models will also provide support and traceability for decisions around organisational culture fit in the future.

As the modelling of extended enterprises (or enterprise system of systems) becomes more common, MBSE will support the efforts through management of the interfaces within the extended enterprise. The models of organisational culture of the component enterprises could be used to assess those aspects that will be constructive and beneficial to the extended enterprises' goals, which factors are likely to inhibit the enterprises, and could be used to identify the possible areas of difficulty of two or more organisations working together.

Note

1. Rasman combines identifying and setting culture into one chapter.

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Notes on contributors

G.A.L. Kennedy is an Associate Research Fellow at the University of Wollongong researching applications of MBSE for the Australian rail industry. Grace holds a MEng in Systems Engineering from Loughborough University. She has expertise in Organisational Systems Engineering (modelling enterprises as systems, particularly the integration of "soft"/human aspects of organisations into these models). Prior to immigrating to Australia, Grace was a researcher at the Systems Engineering Innovation Centre at Loughborough University. She has also worked in the UK Defence industry at BAE Systems. Grace is a CPEng (Systems Engineering) through Engineers Australia and has attained CSEP status through INCOSE.

F. Shirvani holds a BSc in Computer Sciences, MSc in Enterprise Architecture and a PhD degree in MBSE. He is a research fellow and lecturer in SMART Infrastructure Facility at University of Wollongong. Farid has been engaged in modelling the complex infrastructure systems and procurement projects for Transport for NSW and ACRI (Australasian Centre of Rail Innovations) over the last 8 years. Farid has been 'OMG Certified Expert in System Modelling' (OCSMP) since 2016 and is also a member of INCOSE (International Council on Systems Engineering) since 2012. His research and teaching interests are Model Based Systems Engineering, complex systems modelling, developing metamodels and domain-specific modelling languages, knowledge and information management, and customising the modelling methodologies and tools. He has

published his research outcomes in several conference proceedings and international journals.

W. Scott has been engaged in modelling and simulation activities that aim to enhance SE activities. At the University of Wollongong, he has been engaged in examining the application of MBSE to assist the acquisition and modelling of public transport systems for Transport for NSW and Australian heavy rail. These activities have involved a combination of development of modelling practice based on world best practice, examination of application to increase usability and utility of AF tools, and to develop enhanced, customised functionality to automate common activities, increase usability, and reduce effort.

A.P. Campbell is an Honorary Research Professor at the University of Wollongong and recently retired from the Defence and Systems Institute at the University of South Australia where he was engaged in the use of MBSE in defence and infrastructure applications over the last 10 years. Prior to his university appointments, he was a research centre leader and the director of the Decision and Information Sciences Division at Argonne National Laboratory which specialised in the development of decision support tools and analysis for application to complex behavioural problems for US government agencies. He has recently been the director of several projects to develop architecture framework models for the rail industry at UOW, and more broadly to assist in the management and delivery of the complex of transport infrastructure projects that Transport for NSW, Australia is currently engaged in delivering.

ORCID

G.A.L. Kennedy http://orcid.org/0000-0003-0718-4888
F. Shirvani http://orcid.org/0000-0002-0228-5906
W. Scott http://orcid.org/0000-0002-6284-6648

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