Social Complexity and Systems Intelligence in Asset Management Systems

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Abstract. It is well understood that the success in managing assets depends on well-established engineering principles, techniques and processes. Nevertheless, socio-organisational factors also play important roles in asset management systems and asset management activities. Their influence expands well beyond the engineering aspects. This chapter focuses on the discussions on the potential to take into account the social complexity and Systems Intelligence in asset management systems development. It suggests that the momentum to bring engineering and governance together to create the conditions for achieving a successful asset management system is Systems Intelligence, as our ability to behave intelligently in the context of complex systems involving interactions, dynamics and feedbacks is insufficient. This chapter presents eight dimensions of Systems Intelligence within the context of the asset management system, discusses the asset management system as a socio-technical system and as a 'system of systems' and applies basic principles from systems theory as a way to improve our Systems Intelligence to be better prepared to deal with social complexity. It shows how Systems Intelligence can be applied to increasing the chances of success in managing assets. On the basis of these discussions, the future research directions are identified.

Keywords: Asset management system · Social complexity · Systems Intelligence

1 Introduction

1.1 The Need for Systems Intelligence

This chapter postulates that Systems Intelligence, as defined by Hämäläimen et al. [1], can complement the framework and guidelines presented in ISO 55000 series [2], the international standard for asset management. Asset management exists in the context of socio-technical systems, where people in teams, groups and organisations exert their preferences and apply their knowledge in ways that influence the way asset management is performed. Socio-organisational factors, such as motivation and behaviour, influence the performance of organisations by promoting, or not, collaboration, cooperation and learning [3]. Understanding how systems work and how motivation and behaviour interact dynamically is important to manage socio-technical systems. Systems Intelligence connects all these aspects.

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ISO 55000 [2] establishes the Asset Management System as the coordinated elements that define asset management policies, objectives and processes to achieve these objectives. Together with business, financial and regulatory constraints, ISO 55000 acknowledges the influence of the expectation of the organisation and its stakeholders in how to extract value from their assets. Kriege and Vlok [4] confirm that ISO 55000 recognises that leadership, culture, motivation and behaviour can assist asset management in achieving intended goals and ISO 55002 [2] recommends that Human Resources (HR) should support asset management needs. The authors in [4, p. 437] also report that 'it remains unclear to which extent and in which areas exactly HR is affecting the asset management system and identify five critical areas within HR with significant influence in asset management and the asset management system, without offering an explanation of how these critical areas work dynamically together and influence each other. These areas are: (a) Organisational Culture; (b) Motivation and Leadership; (c) Learning and Development; (d) Knowledge Management; and (e) Change Management. To answer the open question posed by Kriege and Vlok [4], this chapter complements the framework in ISO 55000 by considering asset management as part of a larger complex socio-technical system activities, where conflicting motivations often abound, undesirable behaviour may exist and lack of knowledge is the norm rather than exception.

The structure of this chapter is as follows: Sect. 2 describes asset management socio-technical system; Sect. 3 presents important concepts extracted from systems theory and introduces Systems Intelligence; Sect. 4 expands ISO 55000 with aspects that conform with Systems Intelligence; and Sect. 5 concludes the chapter.

2 Understanding the Asset Management Socio-technical System

2.1 The Asset Management Socio-technical System

Asset management provides value for the organisation through the asset. Public assets need to meet strict budget, quality of service and safety goals. Not meeting intended objectives often results in undesirable consequences, whether it is commercial, social or political in nature. According to Hastings [5] asset management aims to answer three basic questions: (1) Does it work? (2) Is it safe? (3) How does it support the business aim? While the nature of engineering focuses on the first two questions addressing the intended effectiveness for the asset, engineering must support answering also question (3) which is associated with the business objectives such as efficiency, profit, customer satisfaction and market share. Differences between engineering and governance create conflicts between engineers and senior management [6]. While engineering tasks focus on technical aspects, governance defines ways to ensure organisations run in the interest of owners, often prioritise short-term goals to maximise immediate productivity and value [6]. Conflicting motivation can cause behaviour that drives decisions that steer the system away from meeting declared intended objectives [3]. The success of asset management depends on how well the asset is managed in the complete life cycle of the asset: from translating the need into specification, acquiring, operating, maintaining, retiring and disposing of the asset. Engineering and business competencies are paramount but they are not sufficient. Furthermore, understanding the system as a whole is also necessary.

Figure 1 shows a graphic representation of the management of physical assets from a social system concept where five classes of actors apply their own specific knowledge to influence the asset management activities in accordance with their own interest [5]. Engineers are concerned with the technical aspects, and often lack of business awareness. Finance specialists see assets as items in a balance sheet and engineering as activities to be outsourced. Senior managers focus on marketing, finances and political issues, and prioritise short-term imperatives. The public always 'want more'; they care about social and environmental issues, but lack of appreciation and understanding about planning, finances and what it takes to acquire and operate assets. Finally, the lobbyists favour specific solutions to achieve their interests.

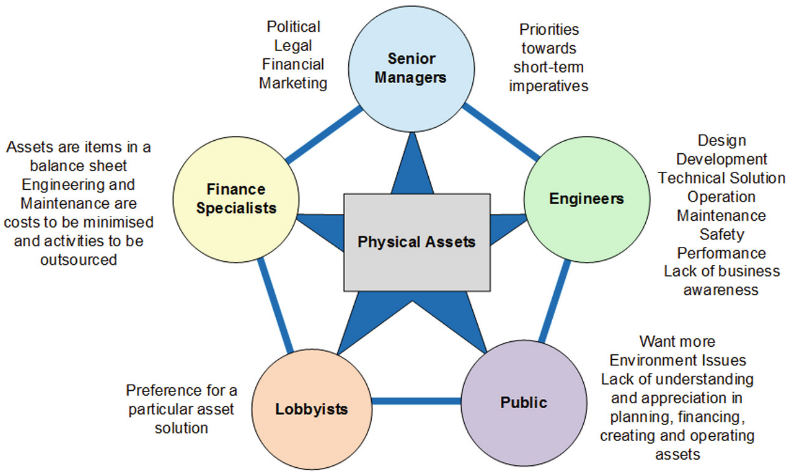

Fig. 1. Asset management social system (adapted from Hastings [5], Sect. 1.1).

Commercial and public assets are influenced by internal and external stakeholders dealing with technical, financial, economic, social and political pressures [3, 5–7]. Managing public assets, in particular, suffers from pressures during the planning phase that may result in 'great planning disasters', as described by Hall [7]. If the asset survives the troubled planning phase, asset management has to deal with adverse consequences throughout the remaining life cycle of the asset.

2.2 The Dynamics of Motivation, Behaviour and Action

Asset Management involves a series of activities applying knowledge, skills and experience to find solutions to satisfy engineering and business needs. To understand the causes of success and failure of knowledge-based activities we need to look into the nature of tasks and the social system that executes them to understand the dynamic between motivations, behaviour and action. The process comprises a series of transformations that transform artefacts, e.g. description of the needs and specifications, from one domain into artefacts in another domain. Lack of knowledge, skills and experience causes distortions that propagate from the definitions of the expressed need to the implemented solution and in the end the solution is likely not to satisfy the need [3]. To correct such distortions it takes longer time and costs more than what was expected. To execute effectively transformations in knowledge-based activities it requires knowledge, skills and experience in three areas: Domain, Technology and Teamwork. 'Domain knowledge' is about understanding the customer's need and the field where the need exists, e.g. public transport, mining, water, energy, etc. 'Technology knowledge' is about application of technology, e.g. engineering, software, business transformations, to find a solution that will satisfy the customer's need. 'Teamwork knowledge' is about knowing how to work together. Knowledge-based activities may fail due to lack of knowledge to engineer the solution, and lack of management knowledge to recognise and plan for this deficiency.

The asset management social system presents a dynamic balance between motivation and behaviour of its actors. The various actors in the system are motivated in accordance with their own preferences and goals, as shown in Fig. 1. Motivation is a private characteristic of each actor and cannot be observed until it is reflected on specific behaviour. Behaviour is any noticeable change or response of a person or a system. Motivation drives behaviour and this drives action [3]. Action is what really matters reflecting into the application of engineering and management knowledge, skills and experience that support the asset management activities or not. Conflicting motivations explain the difficulty of reaching decisions of consensus. Undesired behaviour is harmful to promoting learning, knowledge sharing, cooperation and actions as they do not favour effective and successful asset management.

The theory of behaviour aims to provide ways to predict the likely behaviour of a person in accordance with a classification of personality. Social systems will behave as the result of the collective behaviour of individuals. The behaviour of the system is not expected to respond linearly to individual behaviour, as individuals may influence each other, even in feedback and changing the behaviour of the individual that has started the process of change. Several theories exist to classify people in accordance with personality and behaviour styles which help to describe personal characteristics and predict how a person may behave and perform under certain circumstances [3]. Among those the Life Styles Inventory (LSI) [8] offers a classification of behaviour styles, that helps to understand the dynamics of motivation, behaviour and action. The Life Styles Inventory assesses twelve life styles attributes that form a continuum correlated with the four areas of concern and three characteristics of behaviour defined as 'Constructive', 'Passive' and 'Aggressive'. The life styles are also classified in accordance with their interaction style as Aggressive, Passive or Constructive.

The asset management social system behaves as a problem-solving group searching for engineering solutions to manage complex physical assets within also complex and often conflicting constraints. The effectiveness of problem-solving groups depends on the group interaction style [9] which defines the style of the group as a whole unit, as a system, resulting from the dynamic interaction of its members in accordance with their roles and individual personality styles. The group interaction style reflects the atmosphere of the group, the group's own personality that will promote cooperation or persuasion in finding the solution for the problem. Group members with more power, e.g. in management or leadership roles, political influence or with stronger personality styles are likely to influence other members in the group. Across problem-solving groups, solution quality increases when the group shows a constructive interactive style and decreases with a passive interaction style; and the acceptance of the solution increases with a constructive interaction style and decreases with both passive and aggressive interaction styles. The dynamics of group interaction styles, illustrated in Fig. 2, tells us that constructive behaviour promotes constructive behaviour, and aggressive behaviour suppresses the constructive and promotes passive behaviour, while passive behaviour promotes passive behaviour.

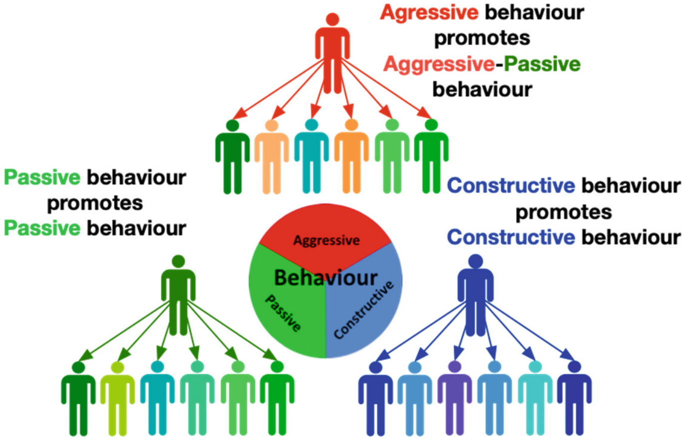

Fig. 2. The dynamics of group interaction styles.

Colours are used to represent the three primary interaction styles: Aggressive (red), Constructive (blue) and Passive (green). Aggressive actors present the characteristic of "just do it as you were told". These actors do not ask for help or help others, and they are not interested in cooperation and how the problem is solved, "just do it". Constructive actors, however, have an attitude of cooperation, helping other actors and do not hesitate to ask help if needed. These actors aim to reach better solutions for the problem, even if it needs more effort and takes longer to achieve. Passive actors have a "don't care" attitude and are satisfied to do what they were told without questioning, even when they believe there are better options. The hue of colours in Fig. 2 represents the degree or intensity of the interaction style of each actor as a combination of the three primary styles. The dynamics of group interaction styles explain that when knowledge-based projects are not performing as expected and interests are at risk, decisions are made within constraints, e.g. unrealistic cost and schedule, which are unlikely to address the lack of knowledge; and often produce undesirable behaviour that decreases motivation and increases passivism, discourages learning and cooperation and worsens the situation.

3 Systems and Systems Intelligence

3.1 Asset Management System as a System of Systems

The asset management socio-technical system has many interconnected components influencing each other. The technical components, or the asset, behave as they were engineered and constructed. Various components comprised in the asset operate as a system, performing a function that was not possible when they were isolated. The asset may change behaviour due to usage and aging, but they are not driven by their own motivation. Therefore, changes in behaviour of the asset can be predicted and should be managed in accordance with their lifecycle. The social system influences the asset and changes itself as people change in accordance with their own motivations, experience and knowledge. Understanding how the socio-technical system works is important to successfully manage the asset.

To complicate even further, management of public infrastructure assets may exist in the context of 'system of systems' that are systems comprised of constituent systems (CS) being managed and operated independently [10]. Constituent systems in the 'system of systems' aim to achieve their own interests and collaborate with other CS motivated by self-interests. A public transport system may comprise several transportation modes such as heavy and light rail, busses and ferries, managed and operated by separate and independent organisations, often with conflicting interests and motivations. Finding the conditions that facilitate the transformation of self-interests in common interests adds complexity to manage assets in 'system of systems', and embracing Systems Intelligence comes to aid this task.

3.2 Systems Intelligence

Hämäläimen et al. [1] define Systems Intelligence as 'our ability to behave intelligently in the context of complex systems involving interaction, dynamics and feedback' [1, p. 15]. The concept of Systems Intelligence is complemented by defining eight dimensions of Systems Intelligence [1, p. 19], shown in Fig. 3. **(1) Systems Perception** is our ability to see the systems around us and understand how various parts in the system are interconnected and influence each other; **(2) Attunement** is the capability we have to feel and tune into systems, modifying ourselves in ways that would change the system for achieving the intended goals; **(3) Reflection** is our capacity to reflect on our thoughts and think about our thinking, aiming to find ways to improve the system and make the system behave towards its intended purpose; **(4) Positive Engagement** is the character of our communicative interactions that will influence and change other parts of the system; **(5) Spirited Discovery** is about passionate engagement with new ideas that will bring solutions to the challenges that always permeate systems; **(6) Effective Responsiveness** is our talent at taking timely, appropriate actions that transform and make the system behave at its best; **(7) Wise Action** is our ability to behave with understanding and a long time horizon, finding and implementing strategies that bring benefits in the long run; **(8) Positive Attitude** encompass our overall approach to life in systems. Systems Intelligence is an emerging competency for engineering, it can be taught and learned and should be included in the engineering curriculum [11].

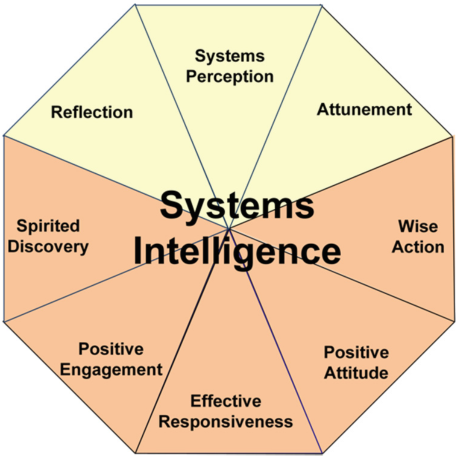

Fig. 3. The eight dimensions of Systems Intelligence [1, p.19].

The importance of systems understanding for managing socio-technical systems is not new and has been expressed by the works of Beer [12], Deming [13] and Senge [14] to name a few. Systems Intelligence helps us to deal with a powerful truth about systems which states that *'the purpose of a system is what it does'* [12, p. 218], as the emergent property of the interconnected components, and not present in any components in isolation. Systems always do what they are capable of doing, not more or nor less. The implication this insight brings is that if what the system is capable of doing does not reflect the intended purpose for the system, then the system will have to be changed. Changing socio-technical systems is about creating systemic structures that establish conditions that drive beliefs and motivations causing people to behave in desirable ways. The way the people behave determines the behaviour of social systems. What people in the system often do not realise is that they can influence the system structure by changing their own behaviour and therefore the behaviour of the system.

4 Expanding Asset Management Framework with Systems Intelligence

4.1 Framework

Framework is a structure of principles, theories, assumptions, concepts, values, and practices that constitutes a way of viewing reality. The framework proposed by ISO 55000 [2] is based on Planning, Operation, Performance Evaluation and Improvement, which is based on PDSA (Plan, Do, Study, Act) model [13]. ISO 55000 acknowledges the importance of the 'Context of the Organisation' (needs and expectations), Leadership and Support (resources, competence, awareness, communication and information) in asset management. ISO 55000 framework is practical in nature, and it does not offer principles or theories to explain how the asset management socio-technical system works. Deming [13] in his 'System of Profound Knowledge' emphasises the importance of appreciating the system as a whole, and in developing theories about how the system works. According to Deming [13], management is about prediction and theory/model is the key to make prediction possible.

The effectiveness and ultimate success of asset management depend on more than engineering and other technical competencies, with dependencies from what could be a very complex social system. Systems Intelligence offers a frame of reference that aids dealing with such complexity. Systems Perception, the first of the eight dimensions of Systems Intelligence, is a central concept, while Attunement and Reflection support the first. Together these three dimensions of Systems Intelligence guide us to develop a better understanding about the asset management socio-technical system. The other five dimensions of Systems Intelligence agree with ‘constructive behaviour’ addressed by ‘Framework for Steering Infrastructure Projects to Success’ [3] and the ‘Theory of Collaborative Rationality’ [15], the latter suggests that a consensus solution should be the goal and often the best for the system. This chapter proposes to expand the framework offered by ISO 55000 with concepts extracted from Systems Intelligence as shown in Fig. 4.

The proposed ‘Framework for Steering Asset Management to Success’ (FSAMS) extends the application of the ‘Framework for Steering Infrastructure Projects to Success’ [3] into asset management. FSAMS incorporates the principle that reflects ‘the aim of the system’, i.e. ‘the system does what it is capable of doing’ [12]. The first three dimensions of Systems Intelligence, shown in yellow, support the application of the ‘system principle’. FSAMS includes three integrated management processes (Knowledge, Motivation and Behaviour) for creating the conditions necessary for ‘steering’ the socio-technical system towards the ‘intended aim of the system’ in asset management.

The framework offers a theory that explains how the asset management socio-technical system works. The theory involves the dynamic of motivation, behaviour and action [3]. Action comprises activities that acquire and apply knowledge. To perform a task effectively and efficiently requires the application of specific knowledge, skills and experience, named collectively ‘Knowledge’.

4.2 Process of Knowledge Management

The Process of Knowledge Management (PKM) identifies the knowledge required, the knowledge available, the gap of knowledge and how to acquire it. PKM addresses the three areas of knowledge presented in Sect. 2.2: Domain, Technology and Teamwork. Domain and Technology (including engineering and science) knowledge is what is needed to engineer and implement the solution effectively. Teamwork knowledge is what is needed “to make it happen” and includes understanding how the asset management socio-technical system works. The Process of Knowledge Management embraces Systems Intelligence as a competency for effective engineering and asset management, and plan for Systems Intelligence to be taught, learned and shared, as suggested in [11].

The Process of Knowledge Management deals with knowledge acquisition and ignorance reduction, explained by “The Five Orders of Ignorance” [16]. At Zero Order of Ignorance (Zero-OI) all is known and there is nothing to be discovered or learned. Zero-OI exists in very simple tasks, which is not the case in asset management. At First-OI

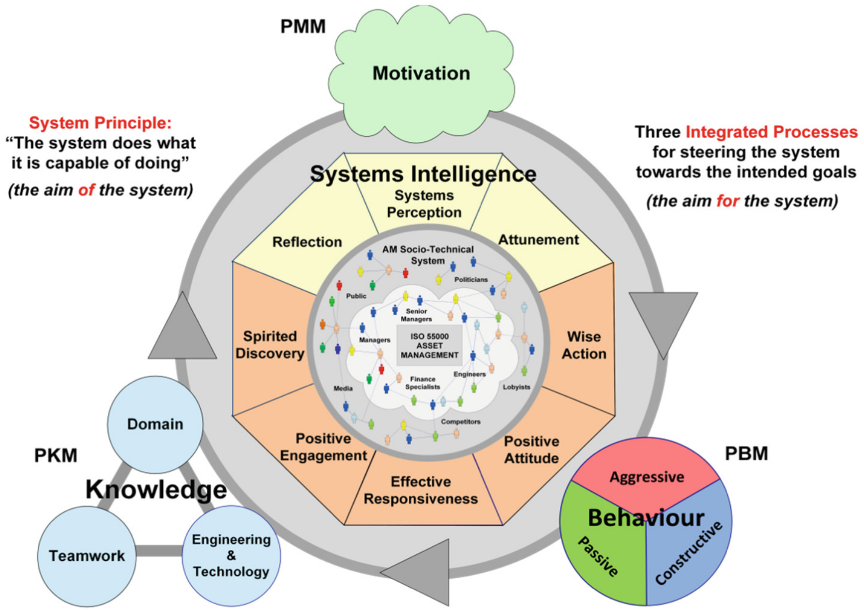

Fig. 4. Framework for Steering Asset Management to Success (FSAMS).

there is a known gap of knowledge that can be acquired through learning and investigation, but nothing is truly 'unknown'. Asset management operates at Second-OI or Third-OI. At Second-OI, lack of knowledge exists but the gap of knowledge can be acquired, and there are 'unknowns' which can be revealed through available processes of discovery. Third-OI is like Second-OI without suitable processes of discovery. PKM identifies what the Order of Ignorance the asset management socio-technical system is in and creates processes of learning and discovery to reduce the Order of Ignorance. PKM takes into account the time and costs needed to acquire the knowledge required and to resolve the "unknowns".

4.3 Process of Motivation Management

The objective of the Process of Motivation Management (PMM) is to create conditions to motivate actors in the asset management socio-technical system to produce constructive behaviour that promotes learning, cooperation, knowledge sharing and ignorance reduction. The Process of Motivation Management identifies key stakeholders that could influence, for better or for worse, the behaviour of the asset management socio-technical system and their motivations. These are likely the actors in the five classes (engineers, finance specialists, senior managers, the public and lobbyists) described in Sect. 2.1 and shown in Fig. 1. PMM also identifies conflicting interests often presented in asset management 'system of systems' as described in Sect. 3.1, and creates conditions to align self-interests with the common goals.

The Process of Motivation Management identifies the ways in which actors in the asset management socio-technical system could be motivated. Most distinctive types of motivation are *intrinsic motivation,* which is associated with performing an activity because it brings satisfaction rather than a reward or consequence, and *extrinsic motivation,* which is the driver for performing an activity in order to attain a separate outcome [17, pp. 55–56 & p. 60]. *Intrinsic motivation* is concerned with self-determination, competence, task involvement, curiosity, enjoyment and interest; and extrinsic motivation is concerned with recognition, competition, money and other tangible incentives [18]. Understanding how the actors are motivated, the Process of Motivation Management develops strategies based on intrinsic and extrinsic motivation factors. The Process of Motivation Management also applies the five behavioural dimensions of Systems Intelligence represented in orange in Fig. 4 (Positive Engagement, Spirited Discovery, Effective Responsiveness, Wise Action and Positive Attitude) to develop motivation strategies.

4.4 Process of Behaviour Management

The Process of Behaviour Management (PBM) identifies behaviour that is favourable to achieve the intended goals and avoid those that do not. Constructive behaviour facilitates learning and collaboration, while aggressive behaviour constrains constructive behaviour and promote passiveness [3]. Aggressive behaviour is present when there are conflicting motivations and the system displays results that diverge from expectations in the form of low profitability, cost overruns, schedule delays, poor quality and loss of market share. PBM may also include processes for assessing and monitoring individual and group interaction styles [8, 9].

The arrows in Fig. 4 show that motivation drives behaviour resulting in the action of acquiring and sharing knowledge. When the adequate knowledge is available, including system understanding, motivation also changes for the benefit of the whole system. FSAMS offers principles, theories and processes that allow us to understand the reality of the asset management socio-technical system. The processes in FSAMS provide guidance to create the conditions to steer the asset management system in the ways that increase the chances of success.

5 Conclusions

This chapter showed that asset management takes place in a complex socio-technical system that cannot be controlled, but it can be steered towards the intended goals by creating the appropriate conditions [3]. The insights offered by Deming's 'System of Profound Knowledge' [13], the 'Framework for Steering Infrastructure Projects to Success' [3], and the 'Theory of Collaborative Rationality' [15] were adapted and applied into the 'Framework for Steering Asset Management to Success' in order to manage physical assets more effectively.

The open questions posed by Kriege and Vlok [4] presented in Sect. 1.1 have been answered by explaining the dynamics that exists between motivation, behaviour and actions that reflect, or not, into learning and knowledge sharing by the adoption of Systems Intelligence. Organisation Culture influences Motivation & Leadership and these are drivers for creating the conditions to foster constructive behaviour that promotes Learning & Development. The processes of motivation and behaviour management, respectively represented by PMM and PBM, proposed in FSAMS, address the dynamics of motivation and behaviour steering Organisation Culture to improve the asset management socio-technical system. The process of knowledge management deals with Knowledge Management and Learning & Development as specific and effective actions to acquire knowledge. Change is the norm in complex systems and embracing Systems Intelligence facilitates Change Management.

FSAMS embraces Systems Intelligence concepts that can be learned by asset managers, engineers and stakeholders in the asset management socio-technical system. The ideas here presented aim to instigate new discussion and consideration. Further work includes assessing the impact of each of the eight dimensions of Systems Intelligence on the development of successful asset management systems, the practical application of the proposed FSAMS and ultimately to report results with case studies.

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