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HC-4-PM: A heterarchical communication framework for project management

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ABSTRACT

Communication software can significantly facilitate the management of large-scale, multi-disciplinary, and complex projects. However, most specialised communication software tools for project management are designed according to hierarchical structures, thus resulting in ineffective project planning and scheduling. To that end, heterarchical communication architectures could allow local decision-making hence enabling agility and robustness against disturbances during project implementation and execution. Furthermore, the majority of software tools and platforms currently applied in project management are commercial while any open-source alternatives overlook features that enable the heterarchical communication among project stakeholders.

This research develops HC-4-PM, a heterarchical communication software tool for project management, to facilitate direct interaction among project implementation and execution teams. Specifically, the architecture of HC-4-PM is based on the principles of Cybernetics (particularly on the Viable System Model) and Operations Research to enable a horizontal project organisational structure and ensure that project management stakeholders share the same level of authority whilst having distinct responsibilities (i.e. heterarchical). HC-4-PM, a first-effort open-source heterarchical communication software tool, contributes to a project's self-regulation and could further assist projects' administration in developing effective project management strategies. This research contributes to project management by providing an open-source software tool for the effective management of communications among project implementation and execution actors in a heterarchical way.

Code Metadata

Current code version	1.0.1
Permanent link to code/repository used of this code version	https://github.com/ElsevierSoftwareX/SOFTX_2019_320
Legal Code License	GNU General Public License v3.0
Code versioning system used	git
Software code languages, tools, and services used	Node.js, Javascript, MongoDB, Vue
Compilation requirements, operating environments & dependencies	Npm, NodeJS, Linux
If available Link to developer documentation/manual	https://github.com/Kyripana/HC-4-PM/blob/master/README.md
Support email for questions	kpanagio@pme.duth.gr

Software Metadata

Current software version	1.0.1
Legal Software License	GNU General Public License v3.0
Computing platform/Operating SystemLinux	Linux
Installation requirements & dependencies	Npm, git, MongoDB
If available, link to user manual if—formally published include a reference to the publication in the reference list	https://github.com/Kyripana/HC-4-PM/blob/master/HC-4-PM%20Documentum%20administrator%20and%20user%20guide_v01.pdf
Support email for questions	kpanagio@pme.duth.gr

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1. Motivation and significance

Project management is a fundamental tool in modern societies which is required for the effective management of human capital, equipment, material, and financial resources [1]. This is particularly relevant to large-scale, multi-disciplinary, and complex projects that could have substantial financial implications like in the case of infrastructure development [2]. For example, over the last two decades, the value of infrastructure projects has been estimated to comprise about 3.8% of the global GDP with projections estimating an increase to 4.1% by 2030 [3]. However, the Project Management Institute documented that US$135 million is at risk for every US$1 billion invested on any type of projects due to challenges in conforming to provisioned project timelines, budget, and goals [4]. Notably, a startling 56% of this amount (i.e. US$75 million) is attributed to ineffective project communication [4], mainly owing to complicated interpersonal relationships and limited trust among the involved stakeholders [5]. Indicatively, in the case of the Airbus A380 program, the impact of poor communication among the dispersed project teams became evident only at the final stage of the aircraft assembly. Notably, during the aircraft assembly it was realised that the components designed by the different teams could not interconnect hence resulting in overrun project costs of US$6 billion and delivery delays of two years [6].

Effective communication ensures that information is circulated via appropriate channels to engaged project stakeholders [5], thus facilitating knowledge sharing to realise project objectives [7]. To that end, successful project management implementation is strongly influenced by the meticulous setup of information flows [8,9], specifically considering that information is recognised as a catalytic driver of project management performance [10]. Paradoxically, the significance of information flows is overlooked within individual organisational entities involved in projects [8]. At a greater extent, the majority of adopted communication methods within organisations are underpinned by hierarchical architectures and procedures that result in project execution delays, mainly owing to the pyramidal structure that imposes cooperation challenges between project actors involved at different levels of the organisational hierarchy [11]. Most significantly, traditional hierarchical structures lack the ability to self-reorganise in case of unanticipated project execution modifications that would require corresponding changes in the organisational structure [12]. To that end, particularly for technically advanced projects, a heterarchical project management style is suggested as this would allow decentralised decision-making within specialised groups of actors [11].

Contrary to hierarchical architectures that follow a top-down structure where higher and lower level entities are clearly identified, heterarchical architectures follow a horizontal structure comprising of distributed autonomous entities [11]. In this regard, heterarchical communication architectures allow local decision-making thus enabling agility and robustness against disturbances during project implementation and execution [12]. Additionally, heterarchical architectures foster intelligence distribution by providing a negotiation-based mechanism. Such mechanisms allow full cooperation among project actors hence contributing to the effective planning and scheduling of tasks [13]. In this context, Dréo and Siarry [14] highlighted the notion of dense heterarchy that underpins information sharing in ant colonies by observing that each individual member of the colony can communicate with any other ant "*at any time and the pieces of information flow inside the colony through many communication channels*". However, the successful realisation of a heterarchical communication system requires the development of respective (typically sophisticated) tools for enabling cooperation and conflict resolution [15]. To that end, the following research question arises: How can heterarchical information flows be realised to enable effective and efficient project management implementation and execution?

This research aims to support effective communication management among project stakeholders. Therefore, to address the abovementioned research query, we analysed, designed, and developed a new digital tool entitled HC-4-PM. In particular, the HC-4-PM is a network-based software tool that allows the effective realisation of heterarchical structures in project management by enabling dynamic allocation of relations in the communication structure. The heterarchical structure of HC-4-PM is based on the principles of Cybernetics and Operations Research. Particularly, with regard to Cybernetics, this research adopted the Viable System Model (VSM). VSM is a methodology that leverages the principles of Cybernetics as building blocks and which has been successfully used for describing organisational structures [16–18]. Furthermore, VSM comprises a 'soft' heterarchical Operations Research-based tool providing the capability to [19]: (i) diagnose failures in systems [20]; and (ii) guide systems to self-regulation thus resulting in fundamental changes in systems' structure [21]. In alignment with Mintzberg [22], this research regards VSM as a suitable representation of the regulatory information flows within firms, particularly considering that organisations are collections of decision elements and channels [17]. Therefore, the development of HC-4-PM was based on VSM as this offers the conceptual language constructs and a theoretically sound foundation for structuring information flows among engaged project actors. This research contributes to the Information Systems design science research via elaborating and formalising VSM through the development of relevant communication software tool.

The remainder of this research is structured as follows. Section 2 describes the HC-4-PM tool by outlining the software's architecture and functionalities. Thereafter, Section 3 presents an illustrative project management implementation scenario of HC-4-PM, while in Section 4 the software tool's impact is assessed. Finally, conclusions, limitations and recommendations for future research are discussed in Section 5.

2. Software description

The key functionality of HC-4-PM refers to the capability to establish heterarchical project communication structures among project implementation and execution team members, enabled by direct text-messaging and data sharing. The acronym of HC-4-PM derives from the statement that depicts the fundamental principle transcending the tool, i.e. "heterarchical communication for project management".

From a technical perspective, HC-4-PM is an open-source software tool which was developed via using JavaScript (Node JS) and particularly the Express.js framework. In addition, HC-4-PM uses the MongoDB as a database system. The VSM structure of HC-4-PM enables data analysis, data visualisation, and data dissemination to support the understanding of data-related failure sources in projects and assist the application of relevant risk mitigation techniques.

2.1. Software architecture

The software architecture of HC-4-PM is based on the basic principles of VSM that were developed in 1972 by Stafford Beer who was investigating common features that could ensure viability in systems [19]. In practical terms, viability in VSM is defined as the ability of a system to continue functioning within a changing environment. In this regard, HC-4-PM can be used either to design a new viable system or to diagnose weaknesses and errors in an existing project implementation and execution system. The five (5) fundamental subsystems constituting the VSM structure, corresponding to specific project-related responsibilities, are [23, 24]:

i. Subsystem 1 (S1) — System-in-focus (implementation responsibility).
ii. Subsystem 2 (S2) — Attenuation of oscillations between subsystems (coordination responsibility).
iii. Subsystem 3 (S3) — Management of subsystems (control responsibility).
iv. Subsystem 3* (S3) — Audit of subsystems (auditing responsibility).
v. Subsystem 4 (S4) — Future planning for long-term viability (intelligence responsibility).
vi. Subsystem 5 (S5) — Corporate ethos (policy responsibility).

The structure of VSM comprises of six (6) main communication channels [24], namely:

i. Channel 1 (C1) is the corporate intervention channel of instructions and corporate standards linking S3, S4, and S5 to the operational units in S1.
ii. Channel 2 (C2) is used in S3 to manage and control the provision of resources along with the resources bargaining between the operational units in S1.
iii. Channel 3 (C3) is the internal communication line and exchange data link among the operational units in S1.
iv. Channel 4 (C4) is used to manage communication between the environment and the operational units in S1.
v. Channel 5 (C5) supports coordination processes among S2, operation units in S1, and control in S3.
vi. Channel 6 (C6) provides auditing to S3* with direct access to S1 activities.

In addition, the 'Algedonic' channel, that ensures the direct link between S1 and S5, is activated in case of infringement of project policies [25]. The interrelations among the subsystems (i.e. S1–S5), along with the respective communication channels (i.e. C1–C6), are depicted in Fig. 1. VSM has also several horizontal channels that support the two-way interaction and communication between: (i) S1 and the environment; (ii) S2 and the environment; (iii) direct management and operational units in S1; and (iv) S1 and S2 operations.

2.2. Software functionalities

At this stage of development, the HC-4-PM software tool can support communication among project stakeholders by providing a range of functional features while facilitating heterogeneous data structures and workflows among project processes. In summary, the main features of HC-4-PM include:

i. An 'Administrator Interface' which provides the option to a project administrator to create a new project or edit an existing one. Detailed software functionalities in the 'Administrator Interface' include:
   - Add a new project member as a 'User', with all his/her details and ability to edit them.
   - Edit an existing project, allocate users in projects, and manage the heterarchical structure of participating users, subprojects, and communication channels via configuring accordingly the authorisation settings.
ii. A 'User Interface' which allows conversation among engaged project actors. A user, following a log-in process to HC-4-PM, can directly interact with other users (i.e. via direct text-messages) by following a pre-structured heterogeneous communication channel. The possibility of establishing multiple connections is also provided.

3. Illustrative example

In this section, the functionalities of the novel HC-4-PM communication software tool are illustrated via the conceptual case of an infrastructure development project. In particular, the illustrative example of HC-4-PM demonstrates the three VSM functionalities, including: (i) five necessary subsystems (i.e. S1–S5) for the classification of the project's team members/stakeholders; (ii) six communication channels (i.e. C1–C6) determined by the project administrator via the tool's authorisation settings panel; and (iii) a 'User Interface'.

3.1. Subsystems

A project administrator, through subsystems S1–S5, is able to classify users according to their role and project-related responsibilities (Fig. 2), namely:

- Implementation (S1) — The functionality of S1 consists of semi-autonomous units which interact with their local environment and among each other in order to perform local operational tasks in the subsystem.
- Co-ordination (S2) — The functionality of S2 is to co-ordinate the S1 units to ensure that each of the latter units acts in the best interest of the project.
- Control (S3) — The functionality of S3 is to interpret policy information from both 'higher' (i.e. S4 and S5) and 'lower' (i.e. S1 and S2) functions. Additionally, information concerning the functionality of S1 must be periodically audited for its quality and correctness by the S3* auditing function.
- Intelligence (S4) — The functionality of S4 ensures the policy-making of S5 on a project, while S4 further acts as a filter for the information concerning the functionality of S3 and the external environment.
- Policy (S5) — The functionality of S5 is to balance internal and external factors, while S5 is also responsible for the coordination of the whole project subsystems.

Regarding the illustrative example under study, project actors are allocated to subsystems S1 to S5 as follows: (i) Staff is classified as S1; (ii) Team Leaders/Supervisors are categorised as S2; (iii) Managers are clustered as S3; (iv) Marketing/R&D departments are denoted as S4; and (v) the Managing Director/CEO is classified as S5.

3.2. Communication channels

Integrated information and communication technology systems are really important in a project management environment to ensure information sharing and coordination between stakeholders and the various project implementation and execution entities. Henceforth, the architecture of HC-4-PM allows a project administrator to manage the communication and interaction among subsystems S1 to S5, as well as to ensure coordination and control via the default channels C1 to C6 (see Fig. 3). Except for the aforementioned default communication channels, an administrator has the authority to establish new channels depending on any emerging needs for interaction.

3.3. User interface

A simple 'User Interface' allows project members to interact via the communication channels assigned by the administrator. In particular, the HC-4-PM provides a friendly interface to the users and allows project actors to receive and send data and information according to the properties of the established communication channels (Fig. 4).

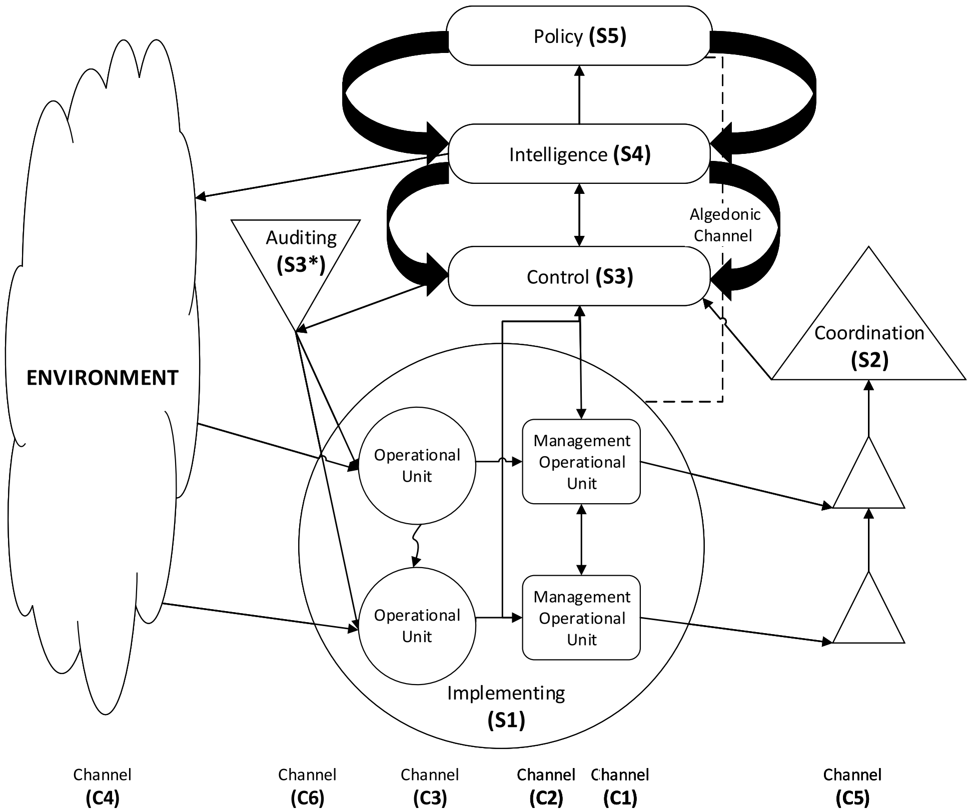

Fig. 1. Overview of the VSM architecture (based on Hildbrand and Bodhanya [26]).

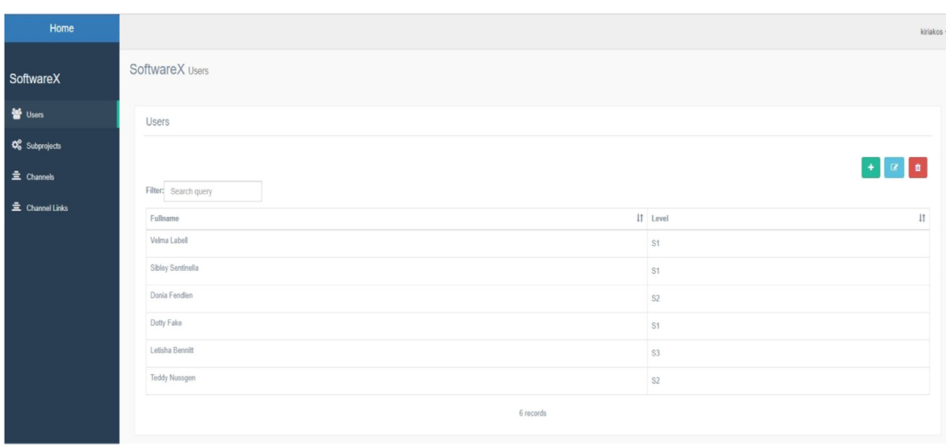

Fig. 2. Defining subsystems in HC-4-PM.

4. Impact and sustainability

In heterarchy, a matrix-based communication structure enables holistic and direct communication among subsystems (i.e. S1–S5), as depicted in Fig. 5, that ensures long-term sustainability via enabling the timely identification and response to any potential risks [27]. To that effect, the HC-4-PM leverages Cybernetics to assess the complexity of project implementation and execution tasks via establishing four (4) mechanisms: (i) vertical communication channels; (ii) horizontal communication channels; (iii) hybrid communication channels; and (iv) material and human resources management jurisdiction. The impact of the communication channels can be encapsulated to the following:

i. Vertical HC-4-PM communication channels simplify the communication among stakeholders and alleviate a set of project management related risks, such as: ineffective communication among stakeholders, lack of ownership and transference of knowledge, delayed action/reaction, conflicts between teams/departments, and diversity of provisioned procedures. According to Stich and Groten [28], an effective VSM structure can eliminate redundant communication links by focusing on the correct relationships among the levels of project hierarchy.
ii. Horizontal communication channels in projects are used to manage the involved subsystems (i.e. S1–S5) in order to support an intergraded informationalisation strategy [29]. As a result, the structure of HC-4-PM can help

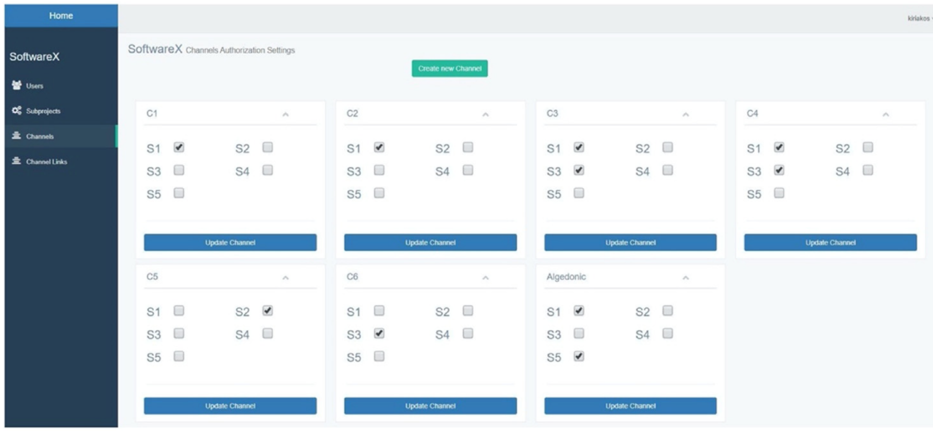

Fig. 3. Establishing communication channels in HC-4-PM.

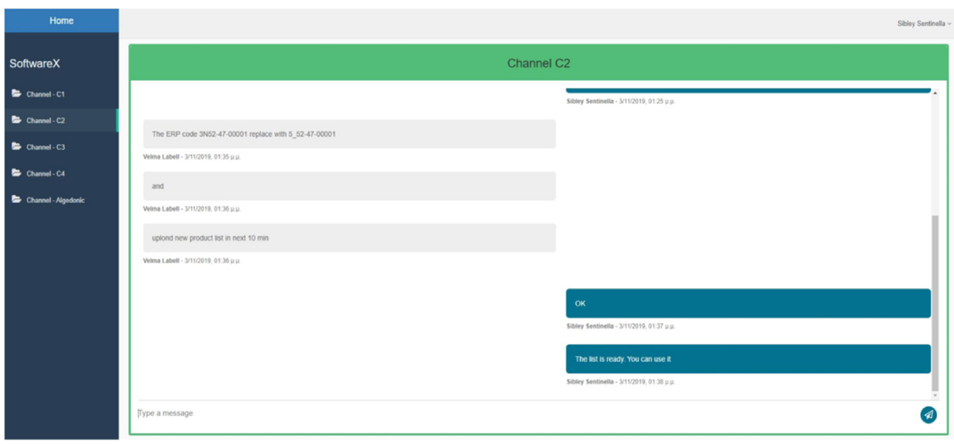

Fig. 4. User interface in HC-4-PM.

mitigate a series of project management related risks, including: employees' resistance to change, inadequate involvement of customers, and internal conflicts between teams/departments.

iii. Hybrid communication channels are important in international business networks to manage the complexity involved in automated production systems [30]. The HC-4-PM, through the hybrid communication channels, can assist in tackling risks (such us the lack or deviation from policy strategies), considering that not all communication channels can support the volume or complexity of information during a project crisis.

iv. The management of material and human resources offers a project the capacity required during pressing situations, such as: limited access to software tools, poor investments in information technologies, and ineffective project team. The HC-4-PM addresses such challenges by allowing direct identification and reporting of such situations hence enabling timely corrective actions.

In terms of sustainability, the HC-4-PM focuses on communication functions and comprises an effective tool for managing and controlling information flows throughout a project implementation and execution team. Moreover, the HC-4-PM provides a set of objective criteria for assessing organisational viability through being able to facilitate direct information flows from other project agencies directly via providing a common communication system.

5. Conclusions, limitations and future research

The Information Systems design science research relies on two knowledge bases, i.e. scientific theories and methods [31]. To that effect, in order to address the enunciated research question, this study was based on the principles of Cybernetics and Operations Research to provide a structural analysis of heterarchical information flows and develop a software tool that could enable effective and efficient project management implementation and execution.

The project implementation phase can be adversely affected by internal communication failure among stakeholders [10]. Therefore, this research adopted VSM, an appropriate language for modelling information flows and communication between project tasks [8]. Additionally, a heterarchical communication software tool was developed, known as HC-4-PM, which allows the effective management of information flows during project implementation and execution. Following the theoretical foundations of this research, the structure of HC-4-PM is based on the concepts of VSM and Operations Research.

We contribute to the existing body of project management knowledge by providing an open-source software tool for the effective management of communications among project implementation and execution actors in a heterarchical way. Specifically, this research contributes to the Information Systems design science research via elaborating and formalising VSM through a communications-focused software tool. The HC-4-PM tool is

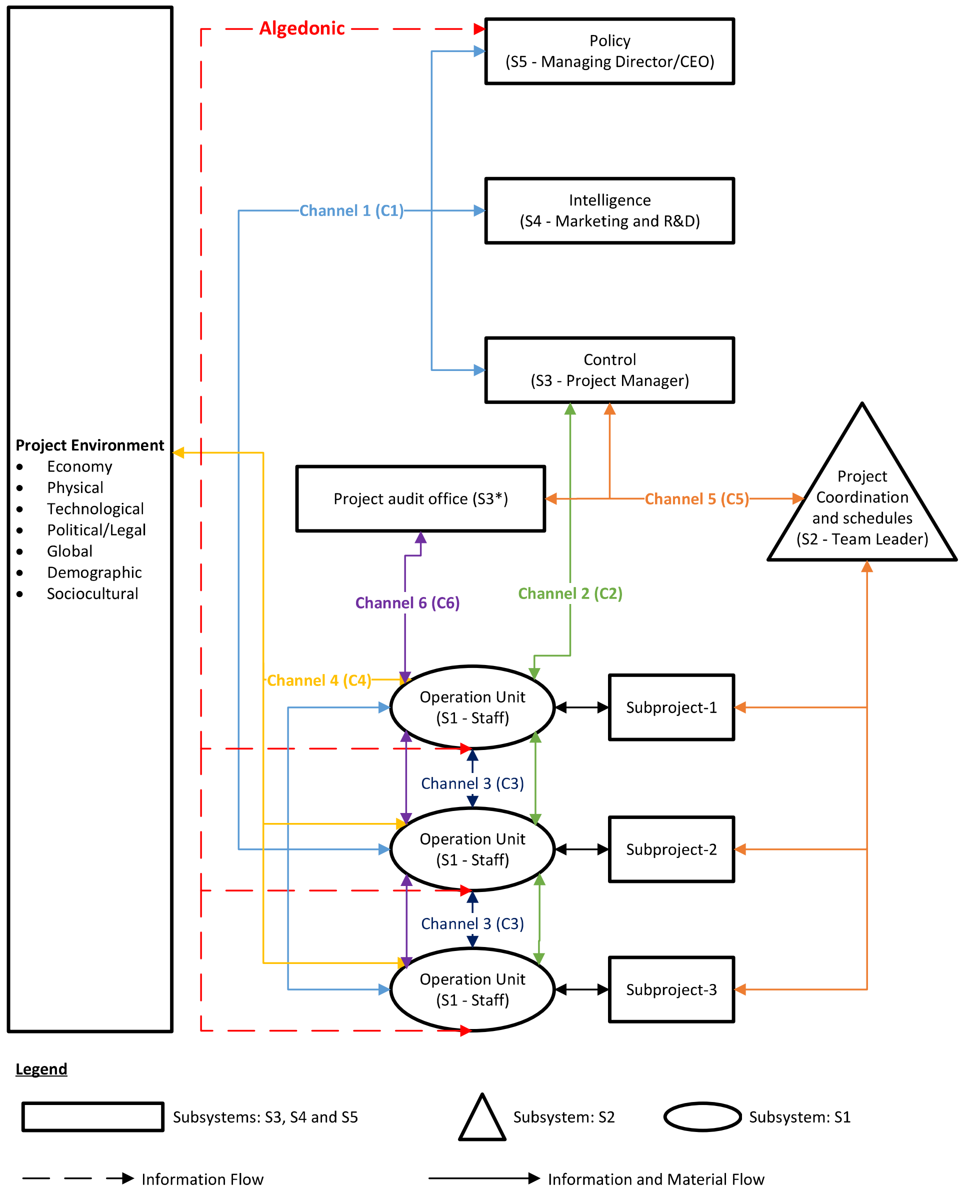

Fig. 5. Heterarchical communication structure enabled by HC-4-PM.

freely available to the community and it could be reused and redistributed by interested stakeholders hence increasing the possibility of improved communication and collaboration in project management environments.

However, few limitations underpin this research which, however, provide opportunities for future research. Firstly, VSM can be approached from different perspectives hence entailing diverse interpretations [32–35]. Secondly, the structure of HC-4-PM is fairly conceptual and needs further testing and validation via real-world empirical studies, whereas the identified VSM subsystems and respective responsibilities (i.e. implementation, coordination, control, intelligence, policy) are arguable. Thirdly, the HC-4-PM software tool is at an early stage of development and should not be considered comprehensive.

With respect to future scientific directions, we will continue enhancing the capabilities of the HC-4-PM software tool according to the design science research framework [31]. We also aim to expand the functionalities of HC-4-PM by, for example, enabling all possible means of communication like electronic mail, instant messaging, file sharing, and videoconferencing. We further envisage to implement and test the HC-4-PM in real-word project management environments to monitor users' communication efficiency and identify useful software modules that could be integrated at a future stage of development.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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