

Article

Model for Global Quality Management System in System of Systems

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Abstract: This study inaugurates an innovative field of research for *Global Quality Management System (G-QMS) in System of Systems (SoS)*, integrating emerging and rapidly evolving disciplines of QMS, SoS Globalization, and Systems approaches, chiefly Systems Thinking. This manuscript introduces, for the first time, a conceptual model for G-QMS in sectors of SoS, developed from an extensive field study conducted in real SoS global organizations, employing the Grounded Theory methodology. We found that this model can be described by two separate supra entities, despite their extensive interrelationships. This manuscript focuses on the first supra entity, which constitutes the foundation for understanding the second supra entity. The model pertaining to the first supra entity, named *G-QMS of G-Organization in Sectors of SoS*, is introduced through a detailed description of its structural principles. Additionally, a detailed description of its complementary aspects and elements is provided, which condenses these principles into a complete conceptual model picture. This field of research is highly significant for such organizations. These organizations typically maintain leading and advanced quality bodies, especially in comparison to the broader industry. Therefore, the G-QMS model developed through this research can offer substantial contributions to these organizations, but also to all other global organizations.

Keywords: Quality Management System (QMS); Global Quality Management System (G-QMS); System of Systems (SoS); global management; systems theory; systems thinking; field study



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1. Introduction

1.1. Rationale

The current research integrates the relatively new and rapidly evolving disciplines of *Quality Management System (QMS)*, *System of Systems (SoS)*, *Globalization* and *Systems* approaches, predominantly *Systems Thinking*. It defines a field of research for a *Global Quality Management System (G-QMS) in the SoS sectors*. This is a highly innovative field of academic research that holds substantial relevance for business organizations, especially in the context of their operational systems. SoS describes a collection of independent systems, when integrated, unveils capabilities and behavior beyond their isolated potential [1,2]. An airport is an example of a SoS: complex, integrated environment composed of multiple independent systems working together to achieve efficient, safe, and effective air transportation. Each of these systems operates autonomously but is interlinked to form a cohesive whole that ensures the airport's overall functionality [3]. In particular, these unique capabilities and behaviors of SoS have global deployment, thus necessitating, beside the technological solution, a global organizational framework to support such intricate integrations. Correspondingly, the multi-organizational structures that are built for the common purpose of the SoS require a reference that goes beyond the organizations. We consider these as global organizations (G-organizations), having multi-site deployment across the globe, necessitating an adapted organizational structure, and name them SoS G-organizations. Accordingly, a global QMS (G-QMS) becomes imperative for these organizations.

1.2. Purpose

The current paper introduces, for the first time, a conceptual model for G-QMS in the sectors of SoS, usually G-organizations, that has been developed through extensive field research in real SoS G-organizations. This endeavor aligns with the established QMS requirements and guidelines as delineated by international standards and embraced by a majority of organizations. Alongside the pertinent Systems approaches, chiefly Systems Thinking, which is discerned to be integral to the proposed G-QMS structure. Furthermore, it considers the theoretical foundation created by Agmon et al. [4], which defined eight base anchors pivotal for this model. The domain of G-QMS in SoS is identified as highly significant and necessary for these organizations, with their quality bodies often being at the forefront and advanced in comparison to the broader industry landscape. Therefore, the G-QMS model developed through this research is poised to make substantial contributions to both the scholarly domain and its practical applications.

1.3. Literature Review

The pioneering research on G-QMS in SoS integrates the disciplines of *Quality Management System (QMS)*, *Globalization*, *SoS*, and *Systems Thinking*, each being a new and rapidly evolving discipline. In addition, in combination, they emerge and formulate this innovative field of research. This review includes the separate disciplines to facilitate their integration, laying the foundation for this research work.

QMS in organizations for SoS is required for highly complex professional applications and in appropriate organizational structures. As also explained in Agmon et al. [4], SoSs are characterized by highly complex technological solutions, typically on a large scale, based on the synergy of multiple systems and technologies. Correspondingly, their organizational systems exhibit a high degree of complexity, including sub-organizations and sub-structures, generally with a global geographical distribution, rendering them global organizational systems. Such organizations require an efficient and effective organizational system capable of operating the structural and global system in a multifaceted, demanding, and ever-changing environment, perpetually advancing technology, and in multiple and diverse environments. Accordingly, their QMS must support both current dynamic complexity and future adaptations while meeting customer demands and regulatory requirements, while also giving the organization added value by being a superlative, tailor-made QMS that is exceptionally relevant, effective, and efficient.

From the aspect of **globalization**, global organizations are a relatively new phenomenon whose meanings are yet to be fully explored, thereby having a broad definition [5,6]. Global organizational structures are diverse across sequences, according to the changing requirements and goals of the organization. Accordingly, global organizations today exhibit a myriad of structures that are in a state of continual evolution.

In regard to **SoS**, the field is growing in importance, and consequently, there is a growing interest in its concepts and strategies. However, a review of existing literature on SoS finds that it is in a preliminary state, with a consensus on its definition still elusive, as well as in terms of defining its organizational systems [7–14]. The transition to the accepted modern term SoS is introduced in the works of [12,15–18], while a recent articulation for SoS is documented in ISO/IEC/IEEE 21839:2019 [1] and SEBoK (2023) [2]. Based on the above references, an SoS can be worded as a collection of independent constituent systems (CSs), integrated into a larger system to produce unique capabilities and behavior that are unattainable separately. This research attends that, in general, this represents a global capability and behavior whose realization also necessitates a corresponding global organizational structure. In addition, SoS has distinguished attributes and characteristics that necessitate addressing the technological solution and therefore also the organizational structure. While Systems Engineering (SE) is a relatively established field, the burgeoning interest in System of Systems Engineering (SoSE) poses a challenge for the present systems engineers on the global scale [2]. Thus, considering these aspects of globalization

and SoS, the research regarding the relevant QMS for global SoS organizations is in an embryonic stage.

QMS is based on compliance with the requirements of international standards, which establish a global standard, encapsulating the best practices of quality management and certification. The cornerstone among these is ISO 9001:2015 [19]. ISO 9004:2018 [20], serving as a guideline, expands this framework, and both are suitable for a wide variety of organizations. In addition, ISO 9001 forms the basis for all the sectorial standards that have emerged over the past two and a half decades. These are pertinent as SoS sectors typically relate to these specific sectors. Notable and relevant sectorial QMS standards include AS9001:2016—QMS requirements for aviation, space, and defense (aerospace) organizations [21], ISO 13485:2016—tailored for medical device organizations [22], and ISO 22163:2017—designed for rail organizations [23]. However, the international standards, including the sectorial ones, refer to the QMS of an organization in its broadest sense and lack the relevant and necessary references to G-organizations in general, particularly to G-organizations in SoS sectors characterized by an intricate QMS [21–23]. Therefore, although the sectorial standards include an expansion of requirements, they do not provide a satisfactory answer. As a first aspect, QMS is based on the core principle of these international standards, the *Process Approach*, [19] and similar standards. However, as noted by [24], the Process Approach does not address the level of process complexity of global organizations. Therefore, the corresponding Process Approach that underlies the QMS must be scalable to a *System Approach* to navigate the complexities within global organizational systems, especially G-organizations in SoS sectors. Furthermore, when dealing with the Process Approach, other methodologies, such as *Business Process Orientation (BPO)* [25,26] and *Process Maturity*, are also incorporated. Schematically, *System Maturity* is an expansion of Process Maturity, offering a model for assessing and guiding best practice improvements in organizational maturity and process capability throughout the life cycle of a product [27]. However, existing literature shows that there is still not a single integrated methodology for System Maturity. Yet, at the level of international standardization, ISO 9004, which provides guidelines expanding and deepening the requirements for QMS, promotes the use of System Maturity [20]. Likewise, the sectorial international standards are in development in accordance with this trend, like AIMM for the aerospace sector [28]. The second aspect lies in the certification method for the standard. The prevailing *QMS certification*, according to all current international standards, is based on a binary model—0/1, implying either compliance (certification) or non-compliance. Therefore, it is perceived in terms of the first level only. This model falls short of capturing the essential aspects concerning G-organizations in SoS sectors. Additionally, beyond the absence of the required references to the organizational framework of SoS, the international QMS standards also lack the necessary references to the unique attributes and characteristics of SoS.

Global Quality Management System (G-QMS) is a new term that has not received sufficient attention in the academic research arena. While instances of QMS applications can be found in a global organization [29–32], G-QMS remains undefined, nor is it clearly expressed in the QMS international standards. The literature review underscores the vast potential of G-QMS research, which is still in its infancy [24,29,32–34]. It is clear that G-QMS faces unique challenges due to geographical dispersion, rendering the global element more intricate and pivotal to manage [35]. Despite the substantial impact and importance of globalization, the absence of a global quality management strategy, coupled with a lack of requisite requirements or guidelines, casts ambiguity on the potential contributions of globalization to the G-QMS model. This gap underscores a fertile ground for further exploration and elaboration to better comprehend and define the interplay of globalization within the G-QMS paradigm.

Extending the Process Approach underlying the QMS standards is necessary and aligns with the perspectives and principles of systems theories, which underpins **Systems Thinking**. Similarly, Systems approaches are in the foundation of the SE discipline, from which the SoSE also develops. These approaches are based on the Systems theories that

began to develop from the *General Systems Theory (GST)*, which determined the behavior of a generic system, and based the principles for its operation [36]. Subsequent distinctions emerged with *Open Systems* [37] and *Soft Systems* [38], both of which bear relevance to the discourse on QMS, often considered as Soft Systems due to their inherent characteristics and the nature of their contents. While QMS encapsulates *hard*, tangible elements, such as documentation, metrics, and processes, it equally engages with *soft*, intangible aspects, such as organizational culture, leadership, and employee engagement, crucial for achieving and maintaining quality. In this light, the *Soft Systems Methodology (SSM)* accentuates holism, adaptability, stakeholder engagement, and continuous learning, providing a practical methodology for applying systems principles in complex, real-world contexts [39]. When dealing with G-organizational systems and G-QMS for SoS, Systems approaches should be incorporated, potentially integrating their perspectives, principles, and tools of these approaches into the structures and attributes of SoS. According to the SEBoK (2023) [2], SoS is a relatively new area; hence, the exploration of how Systems Thinking might extend to SoS-specific issues remains limited. Within Systems Engineering, Systems Thinking is an approach to handling global systems, which considers the components of the system as an ensemble, as a *whole* in a *holistic* way but also using the principle of *hierarchy* [39–46]. According to this approach, both SoS and G-QMS should be treated as a hierarchical system that requires a holistic view, to which the concept and principles of Systems Thinking can be applied. In addition, the elements that Systems Thinking deals with, such as organized complexity, systemic dynamics, self-organization and structure based on processes and relationships, interconnections, as well as emergence, are relevant here as well [47]. Systems Thinking holds the potential to offer substantial value and insight in laying the foundational infrastructure for developing frameworks encompassing elements like structure, motion, behavior, dynamics, interrelationships, and interactions, including environmental interrelationships. This approach harbors the potential to contribute to global quality management research [48–50], and due to its interdisciplinary nature, especially within Systems Engineering, it could play a pivotal role in defining and structuring G-QMS for SoS sectors [4].

In summary, Agmon et al. [4] show that “G-QMS is very significant and a necessary condition for global SoS organizations. G-QMS is one of the managerial issues in the main- management of the SoS, and therefore the management of G-QMS is inseparable from the management of the SoS.” However, G-QMS for SoS sectors is yet undefined: an agreed-upon definition, defined structures, and standards for G-QMS in G-organizations in SoS are lacking, and there is a high incentive to advance towards their development.

1.4. Scope

In alignment with the research domain, the model for G-QMS within the sectors of SoS embodies a high degree of complexity, posing a challenge in its articulation and depiction. However, during the development process, we realized that this model manifests through two distinct model segments, each exhibiting a separate expression. Accordingly, in this manuscript, we focus on presenting the development of a model for one of its two parts, designated as *G-QMS of G-Organization in Sectors of SoS*. With the understanding of this model, in the ensuing manuscript, we aim to delve into the complementary model of the second segment and further elucidate the interrelationships between the two models, thereby completing a complete portrayal of the entire model.

2. Methods and Research Design

2.1. Methods

The undertaking of developing this model is based on extensive field research within real SoS G-organizations as an imperative component. Given the absence of a formalized G-QMS structure within these organizations, the independent applications unique to each G-organization are deemed crucial for developing the body of knowledge. The research paradigm employed combines *analytical review* and *structured qualitative research*. The ana-

lytical review encompasses the exploration of the four core disciplines delineated in the literature review—namely QMS, Globalization, SoS, and Systems Thinking—and focuses on the actual and potential interrelationships and interactions among these disciplines. The objective is to create a knowledge framework for this research domain, subsequently integrated into the model development. Within this scope, particular emphasis is given to the QMS international standards (as cited in the literature review) to serve as a common base for the QMS model. In addition, both literature and internal-organizational documents, obtained through field engagement within the organizations and contributions from research participants, have been incorporated as a direct and detailed source. This structured, qualitative research adopts Grounded Theory as its theoretical and methodological framework [51–53]. Grounded theory, a leading approach in qualitative research, aims to formulate theoretical explanations in an inductive manner through a systematic and attentive analysis of field-collected data representing the studied phenomena [53]. This methodology is committed to a bottom-up methodical explication of phenomena, aimed at theory construction. Given the intricate, ambiguous, and dynamic nature of the research field, quantitative models fall short of capturing the essence, thereby necessitating a qualitative analysis capable of articulating the emerging complexity and nuances from the field. The qualitative approach includes a multitude of variables in a multi-layered manner, demanding a holistic approach where extricating individual variables from the overarching context is not feasible [54]. Employing Grounded Theory, this research adheres to a systematic and stringent methodology for data structuring, collection, and analysis until a coherent theory materializes [55,56]. This methodology evolves in tandem with the research process and analysis stages, allowing for adjustments and refinements into the theory that is being built based on insights and themes that emerge during the analytical phases [51,52].

The structured qualitative research is primarily based on semi-structured interviews, with interviewees meticulously selected in alignment with the research field, structured within a **4-domain square and a 3-dimensional structure** (as described in Section 2.2.1). This structured qualitative approach not only reveals things broached by the respondents and their perceptions thereof but also relates these things to their locations within the data structure. In this way, beyond understanding visible processes and interrelationships, this approach contributes to understanding internal processes and interrelationships that are usually not visible to outsiders. Furthermore, the research method facilitates a holistic examination of the phenomenon in question, enabling interpretation from both the researcher's and the respondents' perspectives. In this way, the theory construction grounded in the field does not rely only on a constant comparison between data but also on a constant interaction between the researcher and the data. The result of this recursive interplay is a research methodology aspiring to decode the studied phenomenon in a manner that amplifies the potential for profound learning and understanding.

2.2. Research Design

The research paradigm employed a blend of analytical, quantitative, and qualitative methods, as depicted in Figure 1. The qualitative research portion leaned on semi-structured interviews. The analytical component encompassed content analysis methods of the research data and complementary sources, such as literature and organizational documents. The quantitative facet complemented the analytics by counting and scoring the obtained information, defining the assessment scale values, and facilitating cross-content analysis.

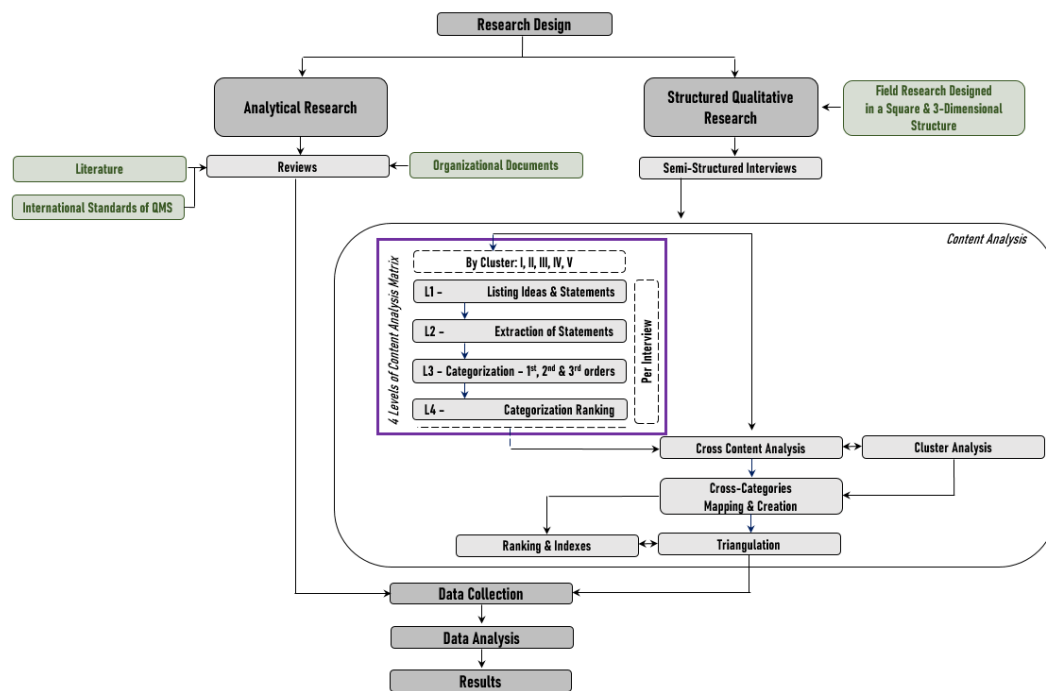


Figure 1. Research design.

2.2.1. Data Structure

The data structure of the research was carefully designed to represent the field from the multifaceted viewpoints embedded within it. This structure emerged from the composite image of the research domain, akin to a “collage” constructed from a mosaic of images. The research involves four industrial sectors: aerospace, light rails, water infrastructures, and medical devices. It focuses on four key occupational arenas: corporate quality management, business and product management, project quality management, and systems engineering—SoS. It also integrates four professional sectors: industry, academy, accreditation bodies for ISO standards, and consultants. Participants were carefully selected based on their senior position and high expertise level. A 4-domain square by a 3-dimension tabular view of the data sources is summarized in Figure 2, with square brackets indicating the count of information sources within each segment. For example, the orange square “Light Rails [11]” indicates the 11 participants coming from light rail G-organizations. The blue square “Corporate Quality Management [29]” includes 29 participants in senior corporate quality management roles from any of the four industrial SoS sectors.

Classification of the research data structure for the field of G-QMS in global SoS organization					
Global SoS organizations sector		Occupational field (in SoS)		Professional sector	
Light Rails [11]	Aviation, Space, Defense (Aerospace) [23]	Corporate Quality Management [29]	Business and Product Management [12]	Academy [5]	Industry [44]
Medical Device [2]	Water Infrastructure [4]	Project Quality Management [12]	Systems Engineering, SoS [10]	Accreditation bodies [4]	Consultants [3]
General – global companies [4]					

Figure 2. The research data structure classification for the field of G-QMS in SoS G-organizations.

2.2.2. Data Collection

Data collection was conducted during 16 months in 2021–2022, with semi-structured interviews—36 in total, each lasting 1–2 h—serving as the primary data source. Complementary data were derived from 5 industrial professional forums and 5 unstructured

interviews, all subjected to identical data analysis methodology. Additional data sources are internal organizational documents uncovered during this phase and combined in the research methodology. Among these are org-charts and structures, contracts, procedures and processes, tools and methods, system databases, and metrics and reports. Aligning with qualitative research methodology, open-ended questions were employed to garner expansive information, detect nuances, and foster deeper understanding, thereby enriching the learning throughout the research journey and enhancing comprehension of processes, interrelationships, and meanings. The research raw data obtained was enormous—extensive and profound, encompassing about 70 h of recorded files, roughly 920 pages of transcripts, over 90 figures and illustrations, and more. To ensure validity and trustworthiness at this phase, as well as to ensure the triangulation in the cross-data analysis phase, all the interviews followed the same defined rules and procedures, albeit with structured adjustments in the questionnaire format based on respondents' domains. In addition, the *snowball sampling* method was applied to identify the target interviewees, while the sample size was determined based on an observation of information redundancy and theoretical saturation from the conducted interviews [57,58].

2.2.3. Data Analysis

Data analysis employed various strategies that demonstrate different technics for data analysis using *content analysis*. These include: *analytical induction*, *constant comparison*, and *counting and quantification methods* to examine the criteria and consistency in the data collection techniques. The validity and trustworthiness have been ensured by additional measures which were incorporated into the content analysis and applied similarly for all data sources. In order to define the content analysis techniques and levels, a sorting of data sources was grouped into five main clusters: (1) Core—G-QMS, (2) QMS of organization, (3) Light Rails sector, (4) SoSE, and (5) Accreditation bodies. For example, with reference to Figure 2, SoSE clusters the research participants who are experts in SoSE and can come from any of the four industrial SoS sectors or the professional sectors. This clustering allowed for a targeted content analysis per cluster, enhancing the granularity and discernment of details and nuances, thereby augmenting the learning potential from the content analysis.

A matrix was employed in the content analysis process, as marked by the purple square in Figure 1. Vertically, the matrix featured four content analysis levels for identifying categories and analyzing their intensity and frequency of repetitions. Horizontally, it was delineated by the five clusters (denoted in Figure 1 by I–V). The analysis proceeded systematically. Each level of content analysis was completed for each of the sources in the cluster, moving from cluster (1) to (5) before advancing to the next content analysis level. In the next step, to enhance the validity and trustworthiness of the study, *cross-content analysis* and *triangulation* were used. Triangulation was used to identify and formulate the main idea categories and examine them, while cross-content analysis was used to deepen learning, particularly regarding the interrelationships between categories and between the clusters. The analysis was conducted in two phases: initially at the cluster level and then across the entire data set. This first enabled a deepening of the analysis in the five arenas of information, mapped to the field of research. Categories were combined by determining primary categories and drawing links between them in order to focus on the relationships between categories and better understand the full potential inherent in the data gathered. Then, the same techniques of cross-content analysis and triangulation were applied to the categories across the entire data.

Throughout the levels and phases of content analysis combined with the qualitative analysis, quantitative data were formulated and counted, that finally consolidated and quantified into three final parameters: **Number of Shows** is the number of similar and related statements and idea extractions grouped under the same final category. **Frequency** is the number of repetitions, counted and summed up for those similar and related statements and idea extractions grouped in the same final category. **Strength** is the level of importance attributed to the category, obtained by counting and summarizing the Strengths as identified

in the related statements and idea extractions grouped into the same final category. The higher the category parameters, the more valid it is deemed. Another parameter determined for the formation is *Maximum Number of Respondents*—from whom the statements and idea extractions were grouped into the same final category. Similar to the other three, this parameter was quantified separately within every cluster and then for the entire dataset. Thus, it demonstrates well the applied cross-content analysis and triangulation. The data collection and analysis at the final stage began with a quantitative view with the four levels of content analysis and continued with the mapping created by the phases of cross-content analysis and triangulation. Moreover, several rules were followed for data evenness in order to ensure a uniform relative weight for each of the five clusters and the entire data.

Finally, for the final results, trace, and display, the first three parameters were consolidated into a weighted parameter—*Significance index (Si)*. This conception is borrowed from guidelines of the risk management standards [59] and is proposed with an adaptation for this analysis. Let a be the number of shows, with b as the frequency and c as the strength. If we consider equal weights for each parameter, then we can define the following: $a^* = a/a_{\max}$, $b^* = b/b_{\max}$, and $c^* = c/c_{\max}$, where all dimensionless parameters are in the 0 to 1 range. Here $a_{\max}$, $b_{\max}$, and $c_{\max}$ are the maximum values obtained for the total of all categories and of the entire data (total data) for each of the three parameters, respectively. With the above definitions, we suggest the Significance index to be a simple average:

$$Si = \left(\frac{a^* + b^* + c^*}{3} \right) * 100 \quad (1)$$

Here, we multiplied by 100 for a clearer representation. Hence, a Total Si can be obtained as the contribution of each of the five clusters:

$$Si_{\text{Total}} = \sum_{k=1}^5 Si_k \quad (2)$$

The next parameter—the maximum number of respondents—is displayed in its relative value. The final results structure centers the two quantitative parameters in a unifying tabular view, which includes the results for each cluster and the total summary of the results.

3. Results

3.1. Subsection Model of G-QMS in Sectors of SoS

Our analysis revealed the complexity and uniqueness inherent in each SoS, especially those with tailored multi-organizational structures. Hence, no singular structure or content for G-QMS in Sectors of SoS could be identified. Instead, the SoS tends to shape the multi-organizational layout around it, along with the G-QMS. The proposed model for G-QMS in Sectors of SoS encapsulates two base supra entities: *G-QMS of G-Organization in Sectors of SoS (G-QMS of G-Org. of SoS)* and *G-QMS in SoS*, as is illustrated in Figure 3. *G-QMS of G-Org. of SoS* is a G-QMS of a multi-organizational structure based on the multi-entity G-organization. This pertains to a G-organization that can be a main contractor (concessionaire) of a SoS project or a contractor of one or more CSs of the SoS in the project and is based on the multi-organizational structures of the G-organization. However, this G-organization is a global company in one of the SoS sectors. The second supra entity, *G-QMS in SoS*, is defined as a G-QMS built for the realization of the SoS project and inherently incorporates structural elements from the G-QMS of G-Org. of SoS. These entities, though separate, share extensive interrelationships in both content and structure, particularly necessitating an understanding of the G-QMS of G-Org. of SoS model to engage with the G-QMS in SoS entity model effectively.

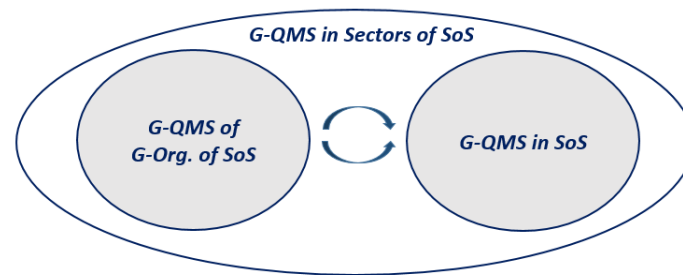


Figure 3. G-QMS in Sectors of SoS model—main conceptual figure.

The research results identify the following main principles that form the G-QMS in Sectors of SoS model. These principles are relevant to the model as a whole but also to each of its two base supra entities separately.

- This is a **model of a global multi-organizational system (G-organization)**, which largely depends on global aspects, mainly the following: (1) A competitive and extremely rapidly changing global business/technological environment. (2) Adjustment to regulatory bodies that are usually characterized by a statutory-political base, making it necessary to adapt to a large number of regulations across the globe and that are changing at a higher and higher rate. (3) People management in the reality of high mobility of people inside and outside the organization and within the multi-organizational structure. As one of the respondents put it, “Where to place the people in the best way, so that they give the best contribution to G-QMS.” In a global company, especially in the SoS sectors, the need for professional expertise is crucial. Consequently, global and advanced companies promote organizational values such as *diversity* and *inclusion*. Another sub-aspect, due to the global organizational deployment, is management that can be done remotely, around the clock, and that allows employee relocation across the globe. (4) Organizational culture in the aspect of a global company with a large structure and worldwide deployment.
- The **model is affected by the G-organization nature**, which is related to aspects such as the following: (1) The type of SoS sector, specifically the field of occupation itself, and how the G-organization interacts with its clients. (2) The G-organizational strategy and the top management commitment to G-QMS. (3) The organizational culture, besides the global ones of the G-organization, as well as its organizational evolution. (4) The level of professionalism of the G-QMS leaders, including the head of the G-QMS and the senior managers who head the local QMSs.
- The **model is based on each of the eight base anchors** identified in the work of Agmon et al. [4], extending and reinforcing them. For example, the dynamic nature of G-QMS in Sectors of SoS across sequences is aligned with base anchor number 8, illustrating variations and transformations in G-QMS among different G-organizations and SoSs and over time within the same entities. The result is that there are a multitude of structures and configurations of both G-QMS supra entities models separately and when combined. Following base anchor number 1, it’s posited that G-QMS should have a corporation’s headquarter entity (G-QMS CORE) [4], which underpins the scale ranging from a distributed to a unified G-QMS structure.

3.2. Content Analysis Final Results

The findings from the content analysis were distinctly organized based on the two models foundational to the G-QMS in Sectors of SoS framework explored in this research. The methodology of Grounded Theory, which allows themes to emerge from the field data through content analysis, facilitated this bifurcation of results in alignment with the two developed models, thereby contributing to the overarching developmental objectives. This paper presents, in Figure 4, the final results derived for the first model—the model for supra entity G-QMS of G-Org. of SoS.

Significance Index						Maximum Number of Respondents						Category	No.
TOTAL	Accreditation bodies	SoSE	Light-Rails	QMSs	G-QMS CORE	TOTAL	Accreditation bodies	SoSE	Light-Rails	QMSs	G-QMS CORE		
23.45	9.51	1.34	5.75	5.36	1.49	0.43	0.67	0.33	0.83	0.22	0.33	Organization's field of occupation - Organization Structure	[3]
3.73	0.97			1.75	1.02	0.20	0.67			0.22	0.33	Senior management leadership	[3.1]
82.73	26.30	3.65	16.96	16.23	19.59	0.47	0.67	0.33	0.50	0.22	0.83	G-QMS	[4]
20.05	13.25	1.03	2.13	2.27	1.36	0.30	0.33	0.17	0.33	0.22	0.50	Professional expertise	[4.1]
16.65	5.65	1.28	4.21	1.96	3.55	0.30	0.67	0.33	0.50	0.22	0.33	Sectorial standardization and its contribution to G-Org.	[4.2]
13.91	0.25	0.25	2.26	2.76	8.39	0.33	0.33	0.17	0.50	0.11	0.83	Quality tools and processes promoted by the G-QMS	[4.3]
12.69	1.68	1.04	4.71	4.33	0.93	0.23	0.33	0.17	0.33	0.11	0.33	Issues and trends in Quality Management	[4.4]
8.42		0.04	1.49	3.76	3.12	0.20		0.17	0.33	0.22	0.50	Organizational culture (including organizational learning)	[4.5]
7.71	5.47		1.04	0.10	1.10	0.17	0.33		0.33	0.11	0.33	Stakeholders for G-QMS (including the client)	[4.6]
3.55				1.56	1.99	0.13				0.11	0.50	Striving for uniformity	[4.7]
50.03	7.44	0.22	6.58	8.19	27.60	0.37	0.67	0.17	0.33	0.22	0.67	G-QMS Structure	[5]
37.24	7.44	0.22	5.64	3.76	20.17	0.30	0.33	0.17	0.33	0.22	0.50	G-QMS CORE	[5.1]
13.23	0.56	0.03	3.10	0.14	9.40	0.23	0.33	0.17	0.33	0.11	0.33	G-QMS CORE policy and concept	[5.1.1]
10.66	3.32	0.08	1.32	1.27	4.67	0.27	0.33	0.17	0.33	0.11	0.50	G-QMS CORE Structure	[5.1.2]
6.72	2.52	0.11	0.40	0.66	3.03	0.27	0.33	0.17	0.17	0.22	0.50	G-QMS CORE manager - persona	[5.1.3]
6.63	1.04		0.82	1.69	3.08	0.20	0.33		0.33	0.11	0.33	G-QMS CORE areas of activity	[5.1.4]
12.39			0.94	4.43	7.03	0.33			0.33	0.22	0.67	G-QMS Structure	[5.4]
7.82			0.94	3.18	3.71	0.27			0.33	0.22	0.67	Structure of the G-QMS	[5.4.1]
4.57				1.26	3.3.1	0.17				0.22	0.50	G-QMS interfaces	[5.4.2]
23.12	2.64	0.69	0.16	16.79	2.83	0.27	0.33	0.17	0.17	0.33	0.33	Structures in QMSs	[6]

Figure 4. Summary of the results that form the base for the G-QMS of G-Organization in Sectors of SoS model.

The final results are presented for each of the five main clusters, grouped from the data sources during the implementation of the content analysis procedure: (1) Core—G-QMS, (2) QMS of organization, (3) Light Rails, (4) SoSE, and (5) Accreditation bodies. The two final parameters formulated from the quantified content analysis are displayed for every final content category. The first and pivotal is the **Significance index (Si)**, and the second is the **Maximum Number of Respondents**. The higher the category parameters, the more valid it is deemed. The final results structure, in Figure 4, centers the two quantitative parameters in a unifying tabular view, which includes the results for each cluster and the total summary of the results. For example, parent category [5], named “G-QMS structure”, consists of category [5.1]—“G-QMS CORE” and category [5.4]—“G-QMS structure”. Parent category [5] obtained $Si_{Total} = 50.03$, where the participants from the Core—G-QMS cluster (with $Si = 27.6$) contribute 55.2% of it. In addition, 0.37% of the entire research participants referred to this parent category, and 0.67% of the participants from the Core—G-QMS cluster referred to it. This table board of the final results provides a coherent representation of the model elements for G-QMS of G-Org. of SoS, as will be elaborated in Section 4.

4. Discussion: Model for G-QMS of G-Organization in Sectors of SoS

4.1. Base Principles of the Model

The model for G-QMS of G-Org. of SoS is fundamentally built on five main principles, which have been derived from the analysis of the current study results and are based on the eight base anchors developed in the work of Agmon et al. [4]. Initially, the general model structure consists of the G-QMS CORE entity and QMSs entities. With QMS_x representing the QMS of organization/division X in the multi-organizational structure (G-organization), the following model principles are elucidated:

Model Principle 1: *An interface (control and reporting channels) exists between the G-QMS CORE and each of the QMSs* (based on base anchors 1, 3, and 8 [4]). The intensity

of this interface varies along a continuum, dependent on the role and responsibility of QMS_x within the G-QMS of G-Org. of SoS, ranging from a weaker to a pivotal interface.

Model Principle 2: Interfaces are also operated between the QMSs (based on base anchors 3 and 8 [4]). Each QMS_x has interfaces with other QMSs, albeit not with all, indicating that interfaces between two QMSs are not guaranteed and could range from non-existent to core-interface.

Model Principle 3: G-QMS CORE is responsible for interface building and its ongoing maintenance (an expansion of base anchors 1,2, 3, and 8 of [4]), as shown in Figure 5. The role of the CORE, as articulated by G-QMS CORE heads who participated in the research, is “to work to connect the various QMSs entities in the G-organization—to create connections between the QMSs; to work to create a flow of information between the various QMSs; to promote the work of synergy between and within the various entities in the G-QMS.” Thus, the emphasis on G-QMS interfaces is driven by the CORE. That is, the corporation’s headquarters pushes the interface forward and higher while constantly looking at or working on it. The G-QMS CORE interface movement operates dualistically along two axes: the regulatory axis (process-theoretical axis) concerning client requirements, other external stakeholders on client behalf, or G-organization top management, and the internal axis pertaining to the G-QMS’s agenda in collaboration with various QMSs. This principle aligns with the Open Systems principles, as articulated in Systems Engineering, outlining a system that maintains reciprocal relations with both internal and external entities, enabling the exchange of knowledge, information, process infrastructures, or other resources [37,60].

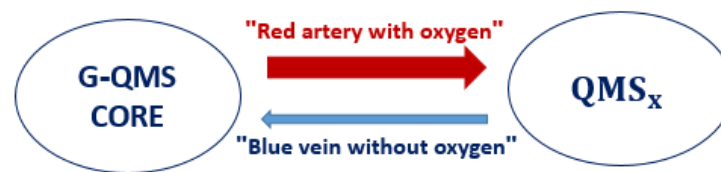


Figure 5. Interface architecture between the G-QMS CORE and QMS_x .

In line with Model Principle 1 and Model Principle 3, the G-QMS CORE is the determinant of the Balance point (B_p) on each of the interfaces between it and the various QMSs. As base anchor 2 shows, the B_p represents the equilibrium position between the two interface entities. The positioning of the B_p closer to one of the two interface entities implies the dominance of that entity over the common interface. Consequently, a B_p located close to the G-QMS CORE characterizes a structure where the CORE has strong control and reporting channels, while the opposite suggests a dominant structure independent of the QMS_x . In this, the variation in these interfaces across the scale continuum produces the heterogeneity in the structure. Interactions and interrelationships between the various entities are pivotal for the proper functioning of the Open system. The optimal functioning of the entire G-QMS is contingent on appropriate interrelationships between the variety and types of entities within it and between it and other systems operating in the environment [61], with the G-QMS CORE playing an active role in this configuration.

Model Principle 4: defining the interface as an entity. Based on base anchors 2, 6, and 7 of Agmon et al. [4], this is one of the essential core extensions in the G-QMS model, especially in the SoS sectors. This finding was raised with great frequency and intensity across multiple cross-categories, particularly within the clusters of SoSE and Accreditation bodies. By extending to base anchor 2, the interface can indeed be perceived as an entity, warranting the definition of a QMS for it, especially for core interfaces. This principle finds additional validation from the GST [62], underscoring that a specific QMS entity is not isolated but has a steady and structured interaction with its environment. Defining an interface as an entity entails delineating the contents, mechanisms, and rules of interaction and exchange between QMSs and the other related systems or the environment. The Systems Engineering definition is defined by the core term *Interdisciplinary*, which refers to the interface between disciplines [63], further underscoring the entity characteristic of the

interface and hinting at the necessity for a QMS definition for it. Moreover, the research results identify that B_p transcends mere control and reporting channels or a balance score on the interface; it signifies a mechanism or entity overlooked in QMS standards (ISO 9001, ISO 9004). Let QMS_{int} be this entity, defined in accordance with the principles of quality management and the local functionality (relevance) where it is located within the G-QMS of G-Org. of SoS structure. In accordance with base anchors 3 and 8, similar to the description of how the interfaces are laid out and their role in the structure, the QMS_{int} entities also move across a sequence, from one end where there is no QMS_{int} but only an interface to the other end where the QMS_{int} includes extensive contents. This implies that not every interface houses a QMS_{int} , and existing interface entities comprise a variety of contents and forms according to their location and role in the structure of the G-QMS of G-Org. of SoS. Initially, identifying the relevant QMS_{int} within the structure is imperative, followed by defining their contents and forms. This practice is requisite for any specific G-QMS of G-Org. of SoS. Finally, the location of the QMS_{int} between the two QMS entities behaves similarly to what is described regarding the location of the B_p . Figure 6 is an illustrated model structure created by the combination of the above four principles.

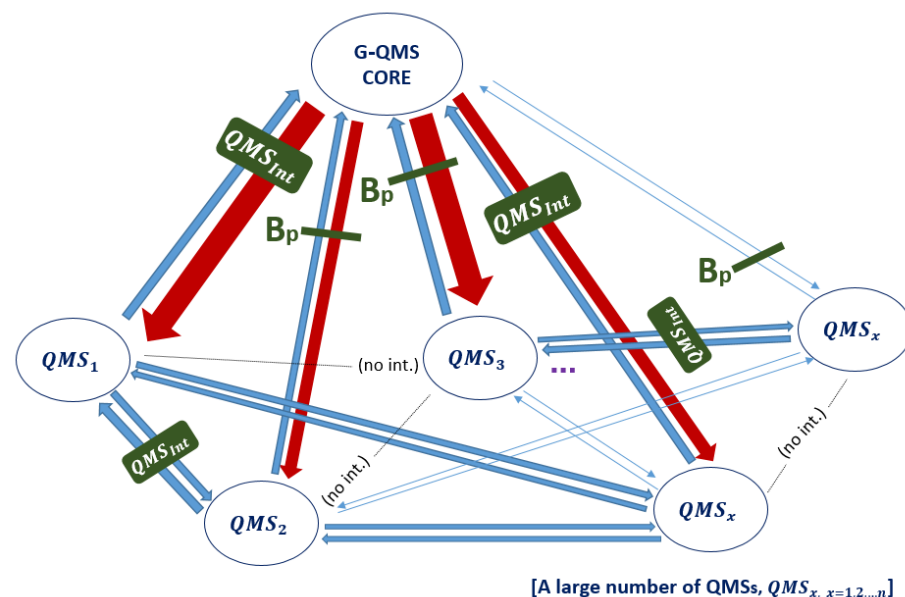


Figure 6. G-QMS of G-Organization in Sectors of SoS model structure based on principles 1- 4.

Model Principle 5: *G-QMS CORE has a transdisciplinary view in the G-QMS of G-Org. of SoS.* Model Principle 5 underscores the necessity for a transdisciplinary view within the G-QMS of G-Org. of SoS, aligning with base anchor 7 and the emergent need for a systemic and holistic view, hallmarks of System Thinking. This theme, highly powerful for quality management, rose in the research findings with great frequency and power. The theoretical foundations laid by GST underpins Systems Thinking, offering principles and concepts that help to understand, analyze, and address the complexity and interconnect-edness of Systems in a *holistic* manner, based on its principles: *wholeness, interrelationships, hierarchy, adaptation*, and others [62]. Systems Thinking, in turn, applies these principles in practical, real-world contexts, providing methodologies and tools for dissecting and resolving complex problems [45]. The term *transdisciplinary*, as newly defined in Systems Engineering [64], replaces the previous term *Interdisciplinary* in the definition to “crosses many disciplinary boundaries to create a holistic approach” [64]. This revised definition of Systems Engineering is significant. It considers the ability to coordinate on many levels, beyond the interfaces. This definition epitomizes a holistic view, critical for SoS and quality management, especially within the G-QMS of G-Org. of SoS model. Consequently, the role of the G-QMS CORE is to produce the transdisciplinary view along the length, width, and

depth of the G-QMS of G-Org. of SoS, necessitating a systems view, along with structures based on System Thinking principles.

The model developed here, in accordance with the base anchors of Agmon et al. [4] and the principles identified so far and coupled with the research results, can be concluded with the following two structural elements: First, the G-QMS CORE inherently strives for uniformity and homogeneity, since that, facilitating effective communication for it and the G-organization's top management, alongside the ability to perform comparable and measurable assessments through uniformed evaluation and measurement tools. However, due to the nature of the G-QMS structure, the whole structure is heterogeneous. Second, in view of the structural aspects presented, in order for the multi-organizational structure of the G-QMS of G-Org. of SoS to be effective and adaptable, **coordination** is required between the various entities of the structure. This coordination is essentially the **inter-face network** between the G-QMS CORE and the other G-QMS entities, and among the G-QMS entities themselves. Naturally, every entity in the structure has responsibility in its territory, and is built to give the professional answer within its limits. However, the emphasis on these interfaces is paramount, as they could be the strength or weakness of the complex, global, multi-organizational structure. The larger and more complex the G-QMS, the larger number of QMS entities, and the broader and more networked the set of interfaces, necessitating increased attention to these interfaces, particularly the core and central ones. The introduction of QMS_{int} addresses the highlighted need for emphasizing interfaces, which often harbor challenges, potential failures, and opportunities for improvements. The QMS_{int} entity, dedicated to quality management of the interface, addresses these challenges and harnesses the strengths and improvement potentials. The research results, as visualized in Figure 4, emphasize this need for building this identified element of QMS_{int} , particularly underscored by respondents across all sectors and occupational fields. The G-QMS CORE's pivotal role in constructing and maintaining these interfaces, and thus their increased engagement with them, further validates that principle, along with the required transdisciplinary operational view in multiple and a variety of entities and interfaces. As can be seen in Figure 4, within the parent category [5], which has $Si_{Total} = 50.03$, the third highest of the research results, an independent sub-category [5.4.2] was identified for the structured interfaces, with a $Si_{Total} = 4.57$, which was referred to by 50% of the interviewees in the Core—G-QMS cluster and 33% from the QMS of organization cluster. Thus, it is indeed the G-QMS CORE that builds and maintains the interfaces.

4.2. Key Aspects in G-QMS of G-Organization in Sectors of SoS Model

Aspects and insights regarding the model were identified and formulated from the application of the concepts and techniques of the field research using Ground Theory combined with the analytical review, throughout the analysis, mapping, and quantification of the research data. The ensuing discussion pivots on the key aspects as revealed from the research findings, encapsulated in Figure 4, in relation to the articulated main principles and the accrued knowledge.

4.2.1. Leadership and Commitment of Top Management

The leadership and commitment of top management emerge as quintessential both at the G-organization level and at the G-QMS level. As the G-QMS becomes larger and more complex, the factor of top management leadership of the G-QMS concurrently escalates. This key factor supports the main principle of the QMS standards regarding the importance of the involvement and commitment of top management for quality management [19]. The magnitude of top management's commitment and involvement in the G-QMS domain directly correlates with the G-QMS influence and vitality for the G-organization. There is great importance to the level and extent of the organizational resources allocated to the G-QMS, in the selection of senior managers, in determining their organizational level, as well as with regard to the backing they receive. Moreover, the extent of top management's involvement in the actualized processes and their encouragement is vital. The involvement

and commitment of top management are crucial for maintaining a valuable and effective G-QMS of G-Org. of SoS. In Figure 4, an independent category [3.1] with a $Si_{Total} = 3.73$ was identified for this key aspect, which is the second largest among the categories for the parent category [3].

4.2.2. G-QMS CORE

The establishment and functionality of the G-QMS CORE are identified as substantial contributors to the structure of the G-organization. Advancements in communication technologies, encompassing both transport and accessibility, and, more significantly, the realm of IT solutions, have facilitated the practical establishment and operation of the G-QMS CORE, especially given the global deployment of the entire G-organization. Essentially, technological advancements have catalyzed the establishment of this head entity, bolstering its power and influence within the entire structure and thereby fostering the promotion of quality management policy and strategy. As can be seen from the research results in Figure 4, an independent category [5.1] with $Si_{Total} = 37.24$ was identified for this CORE entity, the main category for the parent category [5], accounting for 74.4% of it. The emphasis on the G-QMS CORE was echoed across all five clusters, mainly in the Core—G-QMS cluster, where 50% of the respondents referred to it and which contributed to 54.4% of its Si. Moreover, the high emphasis emerged through the identification of four independent subcategories.

1. CORE G-QMS is a direct arm of the G-organization's top management

First, *by striving for uniformity*. Despite the inherent heterogeneity of the G-organization, top management strives for uniformity. The top management's preference for uniformity is rooted in the ease of management that it facilitates: more simplified process management, streamlined IT and other system types, the potential for leveraging "size advantage," resource "smoothing" among various partner organizations, and the ability for comparative auditing and measurement, among other benefits. Broadly, uniformity across the organization paves the way for enhanced efficiency and cost savings. The research results show that the G-QMS CORE entities also strive for uniformity and invest efforts in this. Initially, this is done in line with the top management's pursuit of this, and then through the adoption of QMS standards that delineate a uniform common denominator and thus play an essential role in that uniformity pursuit. The endeavor for uniformity is identified as an organizational value in many global organizations, particularly embedded within the G-QMS CORE policy. However, this pursuit is balanced, not pursued as "*at all costs*" nor as the expression "*I will kill myself for it*", but it rather accommodates diverse architectures wherever essential and beneficial. The primary aim remains the establishment and operation of a most right and apt G-QMS, and this is one with acknowledging and accommodating the inherent heterogeneity. In Figure 4, an independent category [4.7] with $Si_{Total} = 3.55$ was identified for this key aspect, with 50% of the respondents in the Core—G-QMS cluster referring to this.

The second is *by leading the policy and strategy*. The G-QMS CORE is responsible for determining the policy and strategy of the entire G-QMS, derived from the G-organizational policy and strategy, and those that give value to the G-organization. Furthermore, the G-QMS CORE embodies a systems view and a transdisciplinary view, applying principles of Systems Thinking to grasp the broader organizational picture, as echoed by multiple senior G-QMS CORE managers. For instance, the statement, "*the G-QMS CORE sees the whole big picture*" was repeated by more than seven senior managers of G-QMS CORE. In practice, as a policy, the management of the G-QMS CORE is executed through a two-dimensional prism, encapsulating quality management both longitudinally (top to bottom) and horizontally (across the organization). This dual view encompasses a holistic organizational perspective horizontally, capturing elements of quality concepts, vision, mission, business challenges and direction, and policy, while longitudinally, it contemplates the variances across different organizations and divisions. This management approach navigates between promoting uniformity—emphasizing a "one company" ethos—while retaining the flexibility for QMSs to tailor processes within their respective organizations and divisions.

The G-QMS CORE operates across different layers in a transdisciplinary manner, encompassing all entities, interfaces, and components within the G-QMS, including partners and environmental interfaces and, in particular, the stakeholders. Lastly, the G-QMS CORE acts as a comprehensive, synchronizing, and unifying entity within the entire G-QMS, its head having the vantage point to observe and orchestrate activities across all QMSs and also offering a dual, unique perspective—viewing all QMSs collectively and individually from an external viewpoint. The data in Figure 4 illustrate an independent subcategory [5.1.1] with $Si_{Total} = 13.23$, marking this key sub-aspect as a primary subcategory under category [5.1], constituting 26.4% of it. All five clusters referred to this, in particular, 50% of the respondents in the Core—G-QMS cluster, who contribute to 71% of the Si to the subcategory.

2. G-QMS CORE structure

The G-QMS CORE structure is discussed by the following structural elements: Firstly, there are a variety of G-QMS CORE structures in G-organizations, even though they all hail from SoS sectors in this research. This structural diversity extends within sectors, such as different G-organizations in the aerospace or light rails sectors. The unique structure of the G-QMS CORE is influenced by a multitude of factors, including the field of occupation, regulatory and standardization requirements, stakeholders, organizational culture, organizational history and evolution, senior management's perception of G-QMS, and the expertise level of G-QMS's senior management. Secondly, the G-QMS CORE structure is a significant factor in the overall G-QMS structure. Thirdly, the CORE activity encompasses direct actions and matrix activities (through interfaces) vis-a-vis the activity in the QMSs, dependent on the size of the CORE and available resources. The leaner the CORE structure, the more it tends to focus on matrix-interface activity concerning the QMSs. Fourthly, despite resource limitations, the G-QMS CORE often opts for a matrix (hybrid-integrated) approach, where the advantages, on the whole, outweigh the limitations. Accordingly, the structure of the CORE is largely built on the work of the interfaces, emphasizing a strong focus on interfaces from the G-QMS CORE's perspective. Finally, structurally managing the G-QMS demands a transdisciplinary approach, given its high complexity. The results of this research identify two central vectors in this management: firstly, the ability of the G-QMS CORE to manage matrix interactions efficiently (with emphasis on the interfaces), and secondly, guiding the organizational QMS bodies (with emphasis on contents). In addition, the G-QMS CORE conducts direct quality management activities through various QMS entities as well as with other G-organization entities outside the G-QMS, such as the business entities, marking an additional layer in quality management activity. To foster direct quality management through QMS entities, the G-QMS CORE often needs to establish broader (central) work interfaces than the QMS's own interface with its direct managers. Thus, it is striving to create such interfaces across all management levels.

In conclusion, Figure 7 illustrates the resultant structure of the G-QMS CORE, where the core structure is delineated into three layers encompassing direct structure, matrix operations, and hybrids. This structure affords a significant degree of flexibility and agility, catering to the necessity of honing focus on continuously shifting and evolving focal points. The diagram further elucidates the transdisciplinary network fabric structure embedded within the G-QMS CORE, characterized by its comprehensive and layered network. The layering unfolds transversely—crosswise, from inside out, and longitudinally—from top to bottom. This structure facilitates a dual-mechanism network conducive, on the one hand for communication and decision-making and on the other hand for initiative promotion and implementation. The G-QMS CORE's pivotal contribution lies in the creation and maintenance of horizontal interfaces amongst the QMSs within the G-QMS, thereby serving as a matrix for horizontal collaborations between varying organizations and entities.

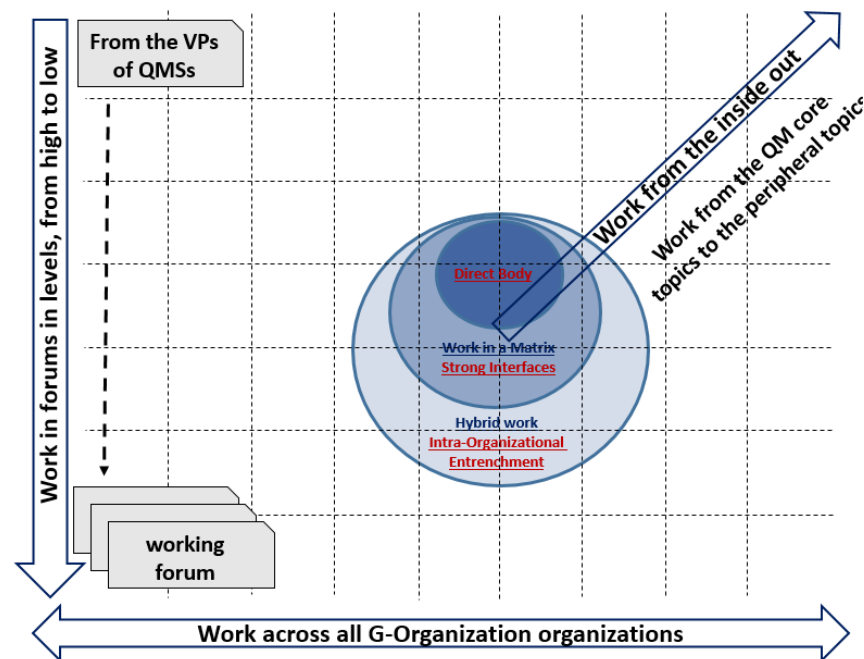


Figure 7. A structural diagram of G-QMS CORE structure in three layers and with a transdisciplinary network.

As per Figure 4, an independent subcategory [5.1.2] with $Si_{Total} = 10.66$ was identified for the G-QMS CORE structure, as the second subcategory in category [5.1], and accounting for 21.3% of it. This aspect of the G-QMS CORE structure was acknowledged across all five clusters, notably by 50% of respondents in the Core—G-QMS cluster, contributing 43.8% of the Si to this subcategory. In addition, 33% of the respondents in the Accreditation bodies cluster contribute 31.1% of the Si.

3. G-QMS CORE manager, the persona

The managerial persona helming the G-QMS CORE is identified as a pivotal component for propelling professional commitment towards the G-QMS CORE's objectives. The imperative for possessing high expertise in quality management is highlighted, establishing this as a prerequisite for attaining organizational validation and authority. The G-QMS CORE manager, being a professional persona, is vested with the capability to steer the G-QMS CORE towards meaningful contributions. Given its typically "lean" personnel structure and a significant dependency on interface management, the effectiveness of the G-QMS CORE is significantly tethered to the managerial persona, alongside the level of commitment from top management and the prevailing organizational culture. Managing the CORE is marked as a challenging endeavor, with success in the role being heavily contingent upon a direct reporting relationship with top management and the staffing of a seasoned organizational manager for the position. Moreover, an ideal candidate is envisioned as one who has evolved within the G-organization, accruing extensive management experience across various segments, thereby fostering a profound understanding of the G-organization. Furthermore, the management and conduct skills required of the G-QMS CORE chief manager in order to be successful in such a position include three main components: (1) systems view ability: navigating multiple vectors simultaneously, embodying a holistic perspective; (2) empathic perspective: possessing the aptitude to comprehend viewpoints on the other side of the interface, coupled with a relentless attentiveness to evolving scenarios; and (3) goal adaptability: establishing clear objectives while retaining the flexibility to recalibrate the approach in response to emergent dynamics.

In Figure 4, an independent subcategory [5.1.3] with $Si_{Total} = 6.72$, was identified for this topic, marking it as the third subcategory in category [5.1] and constituting 13.4% of it. This aspect garnered attention from all five clusters, notably from 50% of respondents

in the Core—G-QMS cluster, contributing 45.1% of the Si to this subcategory, and 33% of respondents in the Accreditation bodies cluster, contributing 37.5% of the Si. It should be emphasized that the importance of professional expertise arises with frequency and intensity across various other categories in the study, particularly in category [4.5] in its reference to the entire G-QMS inclusive of the CORE entity.

4. Areas of activity typical to G-QMS CORE

The G-QMS CORE's activities span across both transverse and longitudinal axes, acting as an orientator in both dimensions. On the horizontal plane encompassing the entire G-organization, key activities include (1) promotion and implementation of supporting IT infrastructures and quality tools, in particular, horizontal processes; (2) advancement of professional expertise for quality management professions in all G-QMS (i.e., instilling the professional techniques and their supervision); and (3) authority over QMS standards and audits. On the longitudinal front, which refers to the more localized, ad-hoc actions within specific QMSs, the G-QMS CORE acts as a theoretical-assisting body. This involves intervening and aiding in the resolution of non-standard or unique problems within particular QMSs, thereby ensuring the effective management and resolution of issues on a more micro-level within the organization. The scope and nature of these activities are inherently influenced by the structural composition of the G-QMS CORE and the resources allocated to it. The conceptual framework of G-QMS CORE's operational realm is depicted in Figure 8, providing a visual representation of its dual-axis operational methodology, emphasizing its role as an orientator in both broad and localized scopes. In Figure 4, an independent subcategory [5.1.4] with $Si_{Total} = 6.63$ was identified for this topic, recognized as the fourth subcategory in category [5.1] and constituting 13.2%.

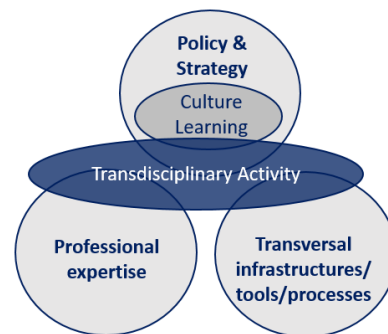


Figure 8. G-QMS CORE concept of activity (mindset).

4.2.3. QMS of Organization/Division

As can be seen in Figure 4, the parent category [6], one of the eight parent categories identified in the study, includes aspects regarding the QMS entity of an organization/division, in addition to the aspects contained in the main parent categories [4,5]. This parent category, with an $Si_{Total} = 23.12$, is acknowledged by all five clusters, primarily by respondents in the QMS of organization cluster contributing 72.6% of this index. The initial aspect discussed is *Belonging*, underlining that the QMS entity of an organization or division has direct responsibility for the organization/division's activity realm. It was found that in most cases, the head of the QMS directly reports to the general manager of the organization/division, facilitating business management of these units. Consequently, each organizational/divisional QMS is crafted and operates in a fashion most apt for the respective organization/division, ensuring that requisite resources are provided similarly to other functional areas within them. Following is the aspect of *Diversity*, which highlights the myriad configurations and structures of QMS within the G-QMS, mirroring the diverse configurations and structures of the organizations/divisions. Interestingly, even among similar organizational/divisional configurations or structures, a spectrum of QMS structures emerges. This variability originates from different perceptions of senior management across organizations/divisions, sometimes leading to QMS structures with gaps.

Furthermore, the QMS entities include direct structures, matrices, and hybrid structures, thereby also showcasing movement over sequence scales.

The third aspect unfolds *two typical structure types* within QMSs: the *closed longitudinal QMS structure* and the *open horizontal QMS structure*. The former encapsulates a full spectrum of quality management functions, aligning with the organization/division's inherent closed longitudinal structure. The latter, being domain-based, encompasses the quality functions pertinent to that domain, extending horizontally across the entire G-organization. This horizontal QMS, marked by a high and advanced degree of expertise, also characterizes the QMS therein, and it also has a much more extensive network of interfaces compared to the closed longitudinal QMS. For instance, the QMS of worldwide procurement and the QMS of the supervision area are examples of open horizontal QMSs. The fourth aspect explores the *Local G-QMS substructure*, where a large organization or division's QMS may embody an extended structure, acting as a substructure of the main G-QMS structure. This configuration houses internal QMS entities, termed local G-QMS substructures, like a subsidiary's QMS. As the G-organization sprawls across more organizations, divisions, and geographical expanses, so does the G-QMS structure, encompassing a broader array of QMS entities spread widely. Correspondingly, an increasingly wide variety of these entities can also be found in the structure, including extended QMS entities with local G-QMS substructures. The fifth aspect, *Local CORE QMS*, posits that a widely spread G-QMS structure would typically encompass one or more central QMS entities, assuming the roles of a local CORE entity. Lastly, the aspect of *Common Denominator* delves into the unifying vectors underpinning the QMS entities: the policy and work of the G-QMS CORE interface and the other G-QMS interfaces. The second unifying vector is the adherence to QMS international standards, embodying a set of unified requirements. Thus, this aspect constitutes the cohesion element in the model of G-QMS of G-Org. of SoS.

4.2.4. Professional Expertise

As can be seen in Figure 4, out of the eight parent categories mapped in the study, number [4] significantly stands out, as it encompasses direct aspects of G-QMS. This category is notably the second largest in the entire research and the largest in the results portion for this manuscript's model, with a $Si_{Total} = 82.73$, accounting for 24.2% of all research results. Likewise, an independent category [4.1] with $Si_{Total} = 20.05$ was identified for this topic, emerging as the most substantial within the parent category [4], comprising 24.2% of it. The accreditation bodies cluster for this category stands out, contributing a robust 66.1% of the Si to the category. The insights from this category intertwine with sub-category [5.1.3] discussed in Section 4.2.2. (3) and other similar statements garnered throughout the analysis of research data. In G-QMS, the degree of dominance of the human factor is largely distinguished alongside other characteristics of Soft Systems. Such systems are socio-technological in nature, addressed through approaches like SSM for real-world complex challenges, particularly those imbued with high levels of social, human, and organizational complexity [65]. The G-QMS managers must be professionals in the field of quality management, in particular, the senior quality management in the CORE and at the head of the QMSs entities. The senior quality management provides professional guidance and support. The necessity for this caliber of professional expertise further escalates within the field occupations of SoS. It was found that the presence of professional expertise is a prerequisite for a contributing G-QMS within the G-organization. A crucial emphasis is laid on the foundational factor for success, advocating that the senior management for quality, both in the CORE and at the head of the QMSs entities, should embody and exude validity and professional authority. This professional standing should resonate well with the bodies within the G-QMS and, more broadly, across the entire G-organization, fostering a culture of quality management professionalism crucial for navigating the complexities inherent in SoS domains.

The G-QMS CORE emerges as an entity dedicated to transmitting methods and professional acumen in quality areas to the local QMSs, thereby fostering the enrichment of

quality professional knowledge. To this end, it coordinates budgets, including the employment of external expert consultants, and strives for training and certification across diverse quality professions. Furthermore, the G-QMS CORE significantly and intentionally facilitates knowledge sharing across the G-QMS structure and works to cultivate organizational excellence and foster a culture of organizational learning. The G-QMS of G-Org. of SoS is characterized as having an internal *legend* that transcends the requisites of the QMS international standards. This includes the incumbents, who are revered as profound content experts, international committees dedicated to professional domains, and well-curated professional organizational literature. In the SoS sectors, the G-QMS is required to achieve professionalism. A cornerstone for realizing this aspiration is the skill level of the personnel designated for Quality for the engineering professions. However, professionalism in Quality transcends beyond this, encapsulating the ability to embody a systems view, and underscores the importance of having Quality personnel who are engineers with systems view capabilities [66,67].

Structurally, the G-QMS necessitates a cadre of highly competent individuals, as mediocrity is not an option. Thus, the management resources of the G-QMS are always directed towards the *people management* aspect. The challenge lies in ensuring the presence of these competent individuals within the G-QMS and, more critically, their optimal placement within and across the G-QMS structure, especially when global considerations do not always align with local ones.

To navigate this complexity, the G-QMS of G-Org. of SoS model unveils a solution embodied in what we term as ***an organizational structure of quality in a matrix that achieves global organizational expertise***. This is a *matrix structure within the G-QMS structure*, which houses content experts or domain masters for each distinct quality area. These domain masters assume the mantle of professionally managing the quality personnel dispersed across the QMS entities, complementing the direct oversight provided by the QMS managers. In this setup, the global expert extends professional service to various local QMS entities. This structural concept makes it possible to produce standardization and harmonization on a global level while simultaneously allowing for flexibility and resource smoothing in the face of frequent changes. However, this structure is based on a strong interface structure, as it relies on extensive coordination and a high level of teamwork between the manager in the local QMS entity and the global content experts. This collaborative effort is envisioned to navigate the inherent conflicts that frequently arise over resources, prioritization, and similar considerations. Figure 9 illustrates an example of this matrix structure, required in the transdisciplinary view along, across, and in depth of the G-QMS of G-Org of SoS. Within this matrix, the core represents the activity amplitude of the quality field of global content experts in the local QMS, categorized across four levels: NA, Low, Medium, and High. This categorization could be predicated on parameters such as amount of personnel and level of professionalism.

Layout of the local QMS entities	QMS_1	NA	Medium	NA	High	Medium		High
	QMS_2	Low	High	NA	High	Medium		High
	QMS_3	Medium	High	Medium	NA	Medium		Medium
	$\vdots$							
	QMS_x	Low	Low	Medium	NA	Low		Medium
		Subcontracting & Procurement	Documentation Control	Project Management	Design Quality	Internal Audits	...	measurement & evaluation

Examples to areas of expertise in Quality Management

Figure 9. An organizational structure of quality in a matrix with global organizational expertise.

4.2.5. The Sectoral QMS Standardization

In Figure 4, an independent category [4.2] with $Si_{Total} = 16.65$ was identified for this topic, making it the second category in parent category [4] and making up 20.1% of it. This category drew attention from all five clusters, with a notable 67% of the responses emanating from the accreditation bodies cluster, contributing 33.9% to the Si. The main aspects discerned from the research findings are elaborated below: First, *various constructions for QMS international standards certification can be found in G-QMS of G-Org. of SoS*: In some constructions, the mantle of responsibility for QMS standards certification rests with the G-QMS CORE, while in others, it solely lies with the individual QMS entities. This delineation extends to the certification structure as well. Some G-QMS of G-Org. of SoS constructions adhere to a singular leading QMS standard accredited by one body, contrasting with those that encompass several QMS standards, where each can be upheld by different accreditation bodies. There is also a spectrum where some QMS entities lack certification to any standard, while others hold certifications to more than one QMS international standard. It was found that this wide array of constructions does not necessarily epitomize an ideal certification framework. Instead, it often mirrors the evolutionary trajectory of the G-QMS of G-Org. of SoS, and by extension, the G-organization, intertwined with the organizational culture and various constraints that shape this landscape.

Second, *the certification of QMS standard is a contributing factor*: Certification to a QMS international standard is known to be a contributing factor to organizations and their QMS [68,69]. However, this research unveils an elevated level of relevance of such certification within the context of G-Org's G-QMS. of SoS. Despite the wide variety of certification constructions, in the G-QMS of G-Org. of SoS, there is great importance to the certification to the QMS standard as a basis for creating a common quality management language among the structural entities, a significance that escalates primarily when certain entities represent the QMS of different organizations in the structure. In essence, holding a QMS standard certification ensures a recognized level of quality management and enables a basis for comparative mapping and evaluation across the diverse entities within the structure. Moreover, it was found that certification to a QMS standard is an important and contributing factor in G-QMS of G-Org. of SoS.

Third, *the sectoral QMS standardization*: The trend of sectoral standardization, which began in the last two and a half decades, reflects a deepening and broadening phenomenon in the realm of quality management. This standardization is based on the ISO 9001 standard but expands it to cater to the distinct requisites of different sectors. It is apparent that this specialized standardization is notably pertinent to those SoS sectors where the ISO 9001 standard alone falls short of addressing the inherent complexities. This aligns with base anchors 5 and 6, as outlined by Agmon et al. [4], portraying the sectoral standardization as a direct manifestation of these anchors. In the context of this research, alongside the ISO 9001 and ISO 9004 standards applicable to all organizations, specific sectoral standards like AS 9001, ISO 22163, and ISO 13485 were examined. The sectoral standards are identified as an augmenting factor, rendering benefits to both the G-QMS and the broader G-organization. The findings indicate that organizations certified to a sectoral standard exhibit a higher level of QMS (*"in a different league"*), in comparison to those lacking such certification, especially when it came to G-organizations. The sectoral standardization already includes extensions to the ISO 9001 standard suitable for all organizations in the sector. However, the study reveals that for G-organizations to SoS, additional expansions beyond these sectoral standards are necessitated.

Fourth, *the structure of QMS standards, particularly the sector-specific ones, is designed in a manner conducive to incorporating necessary extensions*: These standards facilitate the G-QMS of G-Org. of SoS to internally add the essential extensions from its perspective. A few examples elucidate this aspect further. Firstly, SoS sectors are characterized by direct customer quality requirements and/or as part of requirements in the contract and accompanying documents. Sectoral standards, recognizing this, allow for the incorporation of official customer requirements as an integral part of the standard's requisites, thus essen-

tially enabling a tailored response to those additional extensions emanating from customer requirements. Secondly, the adoption of additional standards or guidelines is a characteristic largely pertinent to SoS sectors. For example, the AS9103:2022 [70] guide focuses on the management of key characteristics within the aerospace sector, and the CMMI-5 standard is centered around quality management for design in systems engineering [27]. Fifth, *compliance with many additional standards*: SoS sectors are typically mandated to adhere to prevailing statutory and regulations requirements, alongside numerous technical standards.

4.2.6. Trends and Issues in Quality Management Reflected in the Model

The model reflects notable trends and issues in the realm of quality management beyond the trend of sectoral QMS standardization. In Figure 4, an independent category [4.4] with $Si_{\text{Total}} = 12.69$ encapsulates this topic, with contributions from all the clusters, especially notable contributions from respondents from Core—G-QMS and the Light Rails, contributing 34.1% and 37.1% to the Si , respectively. First, *progress in quality perception: from Quality Control (QC) to Quality Assurance (QA), and from QA to over Mission Assurance (MA)*, was observed. In line with the QMS standards as of 2015, the quality concept transitioned from QA to Quality Management (QM). The data reveal that the aerospace sector has embraced and actualized this transition, while sectors like railway and water infrastructures are in the midst of this transition. A more advanced perception now encompasses QM within the broader purview of Mission Assurance (MA), as can be found in the latest version of ISO 9004:2018 [20]. The concept of MA or *mission excellence* transcends the traditional realm of QA, which primarily aims at ensuring the delivery of a system aligning with time-quality requirements. MA strives for the successful fulfillment of a system's mission. This broader outlook is particularly pertinent in SoS sectors, where the responsibility extends beyond merely delivering a successful system to the client. It mandates the assurance that the system continually serves its intended purpose effectively, aligning with usage profiles over an extended timeframe. The MA perception integrates within the G-QMS entities, thereby broadening the scope and functions of the QMSs, initiating with the CORE entity.

Second, *perception of quality from a place of coaching*. The model showcases the transitioning perception of quality towards a coaching paradigm, shifting from a strictly managerial stance to a guiding and supportive role. The essence of coaching lies in closely accompanying position holders over time, steering them towards excellently, safely, and accurately accomplishing their designated missions. In accordance with the transdisciplinary view, this support is carried out for a variety of positions and at all levels. Consequently, QM evolves beyond merely ensuring that tasks are performed as required across all levels. It now encompasses coaching those other functions to ensure that standards are met at every level, embodying a more nurturing and guiding role in the quality domain. Third, *large global organizations in SoS sectors have leading and advanced quality bodies*. These vast global companies, on the one hand, are characterized by fields of activity that require quality bodies at a high and advanced professional level. They are driven in part by extensive customer requirements for the product and contracts that mandate quality management. On the other hand, given their global magnitude, substantial resources are allocated to their quality bodies, rendering them as leading and advanced entities not only within their respective organizations but also across the industry. Therefore, this advanced stature of these entities within the industry is one of the reasons for the considerable contribution of the G-QMS model developed as part of this research.

4.2.7. Organizational Culture

In Figure 4, an independent category [4.5] with $Si_{\text{Total}} = 8.42$ was identified for this topic, representing 10.2% from the parent category [4]. The clusters Core—G-QMS and QMS of organization contribute 37.1% and 44.7% of the Si_{Total} , respectively. The identified category [4.5] underscores the significance of organizational culture in the G-QMS of G-Org. of SoS, echoing prior findings that link organizational culture to QMS performances [71,72].

Moreover, this element, identified in the fundamental G-QMS in Agmon et al. [4], is strengthened in the results of this study as a key factor in the G-QMS of G-Org. of SoS. This is a *soft* dimension in the model, but it exists, influences, and is even found to be a distinguishing factor between different G-QMS. Within a G-organization, the perception towards the quality field is intertwined with its organizational culture, which extends into its G-QMS. The complexity of maintaining a unified organizational culture magnifies as the G-organization expands globally, encompassing a larger number of diverse organizations. Despite this, the G-QMS CORE actively endeavors to cultivate a culture for quality within the G-organization.

A notable finding within the G-organizations in SoS sectors is the emphasis on Organizational Learning, a concept rooted in Systems Thinking [40]. In this context, it was found that the G-QMS CORE, as well as the other large QMSs, promote the value of organizational learning, dedicating substantial effort towards its organizational integration. This commitment towards organizational learning manifests in cross-organizational processes aimed at prevention, improvement, and the crucial management of organizational knowledge and memory. Managing organizational knowledge and memory emerges as a pivotal challenge for global companies, necessitating a structured approach to ensure accessibility across the entire G-organization. The engagement in organizational learning, equipped with tools and processes for managing organizational knowledge and memory, fosters a rich and extensive organizational legend, reinforcing the organizational culture for quality.

4.2.8. Stakeholders for G-QMS of G-Org. of SoS

In Figure 4, an independent category [4.6] with $Si_{Total} = 7.71$ was identified for this topic, with 9.3% from the parent category [4]. The Accreditation bodies cluster is the main contributor to the category at a rate of 70.9% of the Si_{Total} . SSM aligns with Systems Thinking, and they are particularly relevant in systems situations marked by divergent views and conflicting interests among stakeholders [65]. The needs and expectations of G-QMS stakeholders form the foundation of the QMS standards, with ISO 9004 standard emphasizing this by extending the definition of stakeholders. The *purpose of the organization* is to cater to the interests of *all* stakeholders. This necessitates the identification and mapping of the needs and expectations of each stakeholder and then the creation of a *balance* among all of them to construct a suitable G-QMS of G-Org. of SoS model. Within the G-QMS structure, stakeholders should be identified and mapped in accordance with the general structural layout encompassing the G-QMS CORE, various QMSs, various QMS_{ints} , and environmental factors. A diversity of perceptions regarding stakeholders for G-QMS was found, encompassing both external and internal stakeholders, with the G-QMS CORE perceived as representing the main stakeholders. However, the main and central stakeholder is the customer, as underscored by ISO 9001 and the sectoral standards. The purpose of the G-QMS is first and foremost to meet the needs and expectations of the customer over time. Despite advancements in QMS standards, customers in SoS sectors remain unsatisfied, prompting them to become more and more engaged in the G-QMS. As standardization evolves, customers, at the same time, are augmenting quality requirements beyond it, and they are the ones who drive the establishment and advancement of the G-QMS. The demanding nature of the customer as a stakeholder in SoS sectors underscores the importance of beginning the G-QMS model with customer requirements. The identification and characterization of the customer as a stakeholder is relevant to a large extent in the complementary model of G-QMS in SoS, alongside other typical stakeholders identified on their behalf in the SoS.

4.2.9. Quality Processes and Tools Promoted by G-QMS of G-Org. of SoS

As can be seen in Figure 4, an independent category [4.3] with $Si_{Total} = 13.91$ was identified for this topic, which is 16.8% of the parent category [4]. While all five clusters referred to this, 83% of respondents from the Core—G-QMS cluster contributed to 60.3% of the Si . The findings align with base anchors 5 and 6 outlined in Agmon et al. [4],

demonstrating a substantive realization of these anchors in the quality management tools of the G-QMS of G-Org. of SoS. The current framework of QMS standards requirements is identified to require expansion to cater to G-QMS of G-Org. of SoS, both by incorporating new quality tools (external expansion) and by enhancing existing framework tools (internal expansion). The current field study highlighted nine examples of expanded quality tools promoted by the G-QMS, particularly by the G-QMS CORE. An example provided is the internal extension of the *management tool for internal audits*. Internal audits stand as a robust mechanism for gap identification and rectification, fostering organizational learning and continuous improvement. They hold substantial significance within QMS standards. Moreover, within a large, complex, and globally deployed G-organization, internal audits serve as a comparative and evaluative tool across various organizations and divisions, especially regarding processes executed in disparate centers and with differing output levels. They are instrumental in spotting both gaps and strengths, addressing them at both a local and a horizontal (G-organizationally) level. The internal audits tool in G-QMS of G-Org. of SoS is delineated through a structural diagram (Figure 10), with further elucidation provided in the associated notes (Table 1).

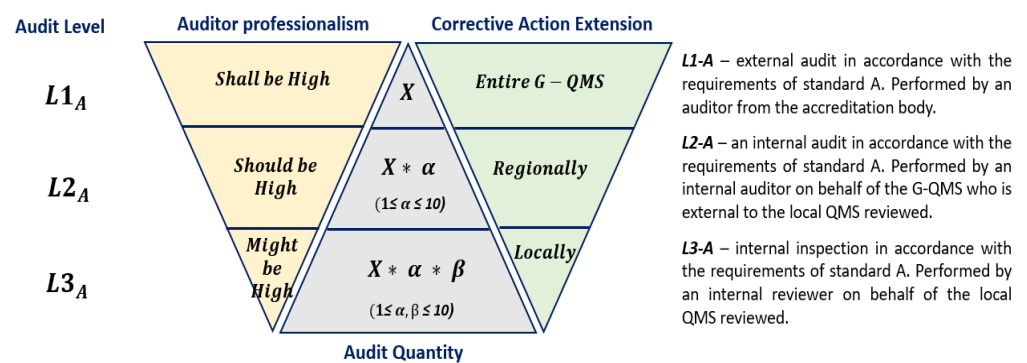


Figure 10. Structural diagram of internal audits tool in G-QMS of G-Org. of SoS.

Table 1. Clarification notes for structural diagram of internal audits tool in G-QMS of G-Org. of SoS.

1	The accreditation body (performing L1-A audits) can be one or more.
2	The number of audits in each level (L) increases at a rate ranging from 1 to 10 as a multiple of the number of audits on the level (L) above. The audits in L3 are usually many, but they are conducted locally—audit scope: time-cost scope per audit is the lowest.
3	In the SoS sectors, in general, the level of internal auditors is adequate (similar to the level of professionalism in other quality areas). In addition, usually, allocated employees for this position only would be found. However, the higher the audit level (L), the higher the level of experience and professionalism of the auditor.
4	The number of audit levels (L) can be greater than 3, but this structure will be preserved.
5	Each audit level is named by a unique term in the structure. The terms can change from one G-QMS to another. For instance: L1-External Audit, L2-Internal Audit, L3-Inspections.
6	The structure in the diagram is shown for standard “A”. If the G-QMS is certified for additional standards, then this structure will be duplicated for each of them.
7	SoS sectors are additionally characterized by customer audits or by other designated bodies on the customer’s behalf. These audits are usually at the regional level, L2, but are performed by an external auditor of the customer or on his behalf. If these audits exist, relevant L3 audits will be added accordingly.

Three further points are made concerning the quality management tools within the G-QMS of G-Org. of SoS. Firstly, a significant aspect of this tool structure is the level 2 (L2) audits, conducted by global content experts from the G-QMS, yet they are external to the

QMS entities being assessed. These audits are notable for their high impact, carried out by professional auditors well-versed in the organizational intricacies, products, processes, and tools. They possess a comprehensive and deep understanding of organizational functions (a longitudinal and depth view) and have a broad perspective, at least at a regional level if not wider, although they are not part of the audited organization. Secondly, G-QMS of G-Org. of SoS includes a unifying and cross G-organizational IT tool for managing the process in compliance with standardization requirements. This tool is tailored internally for each G-QMS to cater to its unique needs. This unifying platform facilitates the management of all audit stages, from reporting findings to reporting corrective actions, and encompasses control and improvement loops. Various entities within the G-QMS access and utilize the relevant data for review and action, with the G-QMS CORE utilizing this tool at a G-organizational level. Consequently, this tool serves as a platform for promoting improvements, fostering organization-wide learning, and preserving organizational memory. Lastly, both external and internal audits are emphasized as potent and significant tool, with its performance levels acting as one of the Key Performance Indicators (KPIs) for the G-QMS.

5. Conclusions and Contributions

This manuscript delves into an innovative field of G-QMS in SoS sectors by proposing a conceptual model tailored for these types of systems. Global SoS organizations are large and intricate organizations from both a technological-system standpoint and a multi-organizational layout. Consequently, as part of the development process, a model delineated by two foundational supra entities was proposed. The qualitative research methods that applied the Ground Theory techniques, in fact, led to discovering this main result. This manuscript sheds light on the model of the first supra entity—the G-QMS of G-Organization in Sectors of SoS (G-QMS of G-Org. of SoS). This articulated model encompasses a meticulous elucidation of the core principles underpinning it. This work also identifies new QMS entities, chiefly the QMS_{int} entities, which are especially ascertained to be important and substantial. This finding is beyond the existing recognition within QMS international standards and, accordingly, extends beyond the acknowledged organizational structures. In addition, the model is presented with a detailed description of its various aspects, thereby enabling individuals to selectively focus on pertinent facets. The G-QMS model developed as part of this study is significantly contributive because it has been developed in the sectors of SoS where organizational Quality bodies are notably advanced and lead the industry. Specifically, the model supra entity presented in this manuscript—G-QMS of G-Org. of SoS (different from the complementary one)—can serve as a referential framework, albeit with necessary modifications, for G-QMS for G-organizations outside the SoS sectors. In conclusion, the G-QMS model conceived through this research significantly augments the operations management research and its application, enriching the burgeoning domain of G-QMS for SoS with innovative and relevant advancements.

5.1. Study Limitations and Directions for Future Studies

The immediate extension of this study entails the comprehensive unveiling of the model for G-QMS in Sectors of SoS by developing the second supra entity model, the complementary model part, depicted in Figure 3 as “G-QMS in SoS.” This entity is directly involved in the realization of the SoS through super project management. It encompasses areas and aspects of QMS that remain unexplored in this manuscript, including the engagement with the characteristics and attributes of SoS. Although the G-QMS in SoS entity is separate from the G-QMS of G-Org. of SoS entity, a profound mutual interplay in terms of content and structure exists between them. Importantly, delving into the G-QMS in SoS model necessitates a grounding in the G-QMS of G-Org. of SoS model, presented in this paper.

Given the introduction of the complete model for G-QMS in Sectors of SoS by establishing its definition and structure, further research directions can delve deeper into specific elements or aspects of the model. For example, presenting the development of

extended quality management tools required in the G-QMS in Sectors of SoS, extending beyond the singular tool presented in this manuscript. Alternatively, further research could delve into the sectoral QMS international standards and develop the relevant adaptations of this field to each sector. However, this work that proposes the model for G-QMS of G-Org. of SoS already enables further research that deals with the operational aspects of G-QMS. For example, conducting a comparative study with G-QMS in non-SoS sectors, for instance, with operations models such as XPS systems [73]. Those kinds of works may also further enhance the robustness of our proposed model. Another research direction can focus on further validation of this introductory model. This direction can continue the usage of qualitative studies by expanding the range and scope of participants. On top of that practice, it is also recommended to select additional research methods.

This development work was based on extensive field research, using the Grounded Theory methodological methods for data collection and analysis. The implementation of these methods, particularly in data analysis, demands substantial effort and resource investment, entailing a meticulous multi-phase analysis. Given the burgeoning advancements in Artificial Intelligence (AI), it is proposed to amalgamate AI capabilities in such analyses. The integration of AI holds promising potential for enhancing the efficiency and accuracy of complex, large-scale qualitative data analysis processes, potentially leading to enriched outcomes.

Nomenclature and Definitions

G-organization—a global multi-organizational system, encompassing organizations distributed geographically across one or more countries. It features a corporate senior management overseeing activities that go beyond national borders.

G-QMS—Global Quality Management System, which refers to QMS tailored for a G-organization.

G-QMS CORE—denotes the corporate senior management entity of the G-QMS.

QMS_x—represents the QMS of organization/division X within the multi-organizational structure (G-organization).

SoS—System of Systems is a conglomerate of independent constituent systems (CSs) integrated into a larger system to deliver unique capabilities and behaviors unattainable individually. Typically, this is global capability and behavior, whose realization necessitates a corresponding global organizational structure. SoS carries distinct attributes and characteristics necessitating technological and organizational addressable.

CS—a Constituent System is an autonomous system with its development, management goals, and resources, contributing to the unique capability of the SoS through interaction. A CS can be a part of one or more SoSs [1].

G-QMS in Sectors of SoS—refers to G-QMS in G-organizations operating in the field of occupations (sectors) of SoS.

G-QMS of G-Organization in Sectors of SoS (G-QM of G-Org. of SoS)—refers to the first supra entity of G-QMS in sectors of SoS, rooted in the multi-organizational structures of the G-organization. The G-organization could either be a main contractor (or concessionaire) of an SoS project or contractor of one or more CSs in an SoS project, functioning as a global company in one of the SoS sectors; **G-QMS in SoS**—refers to the second supra entity of G-QMS in Sectors of SoS, built for the realization of the SoS project. This entity inherently assimilates structural elements from the G-QM of G-org. of SoS.

Balance point (B_p)—a structural element in the model referring to the equilibrium position between two interface entities. The proximity of B_p to one of the two interfacing entities denotes the dominance of that entity in influencing the common interface. The variable locations of B_p across the scale continuum are a factor producing heterogeneity in the G-QMS structure.

QMS_{int}—designates a QMS entity serving as an interface entity, defined per quality management principles and aligned with the local functionality where it is situated in the G-QMS structure.

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