systems

MDPI

*Review*

# Smart Agri-Region and Value Engineering

**Raúl Pastor [1,*], Pablo G. Rodriguez [2], Antonio Lecuona [3] and Juan Pedro Cortés [4,*]**

[1] Seam Start-Up, POLYSOL GESTION, 28030 Madrid, Spain
[2] Department of Computer and Telematics Systems Engineering, University of Extremadura, Av. Universidad, s/n., 10003 Cáceres, Spain; pablogr@unex.es
[3] Instituto de Desarrollo Tecnológico y Promoción de la Innovación Pedro Juan de Lastanosa, Universidad Carlos III de Madrid, 28911 Leganés, Spain; lecuona@ing.uc3m.es
[4] Department of Construction, University of Extremadura, Av. Universidad, s/n., 10003 Cáceres, Spain
* Correspondence: raulpastorgarcia@coiim.es (R.P.); jpcortes@unex.es (J.P.C.)

**Abstract:** Agriculture and silviculture offer interesting opportunities for food, energy, and construction sectors, but to transform such raw materials into valuable products, multiple engineering works must be carried out within R&D, innovation projects, and programs. The classical official decision to promote or supervise such projects involves many agents and criteria but rarely considers engineering quality, reusability, or other valuable and measurable attributes considered in ISO 25.000 or in value engineering guidelines. Missing them would increase technological, business, and programmatic risks, potentially wasting public money or credibility. Large projects are not free from these risks, and it is not a kind of madness to derive R&D and innovation funds to enable access to such valuable knowledge comprehensively, with models. In this context, communications and services, construction, and renewables play a crucial role in smart rural environments. Model-Based Systems Engineering (MBSE) and generative Artificial Intelligence (AI), combined with Natural Language Processing (NLP), are expected to help Knowledge Management (KM) in engineering and governance to supervise value engineering and their relationship with other metrics. Starting with a motivational and multidisciplinary framework for a smart rural transformation for System of Systems (SoS), the authors conduct specific bibliographic research on MBSE-NLP-AI use for automatizing systems engineering supervision at program governance levels.

**Keywords:** smart rural; system of systems; program governance; communications and services; construction; solar energy; MBSE; AI; NLP; systems engineering; value engineering

check for updates

Academic Editors: Michael Henshaw and Siyuan Ji

Received: 3 May 2025
Revised: 30 May 2025
Accepted: 1 June 2025
Published: 3 June 2025

**Citation:** Pastor, R.; Rodriguez, P.G.; Lecuona, A.; Cortés, J.P. Smart Agri-Region and Value Engineering. *Systems* **2025**, *13*, 430. https://doi.org/10.3390/systems13060430

**Copyright:** © 2025 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (https://creativecommons.org/licenses/by/4.0/).

## 1. Introduction

Europe is immersed in an energy and ecological transition and faces important demographic, defense, and citizen security challenges [1]. The fundamental assumption for contextualizing this research is that rural populations, also in transition, because they are producers of ecosystem and food services, can be a priority for engineering professionals due to their evident vulnerability. To empirically verify this assumption, the opportunity should be provided and monitored. One way in which the related professionals can contribute to this transition is through their work on innovative projects, for which they can use new technologies, specifically the so-called Key Enabling Technologies (KETs) [2]. Many of them are still lacking regulations for use (AI, UAVs-RPAS, BIM, additive manufacturing, IoT, 5G, satellites, biotechnologies). These technologies can be assessed and utilized responsibly, necessitating governance for procurement or funding to complement existing regulations.

The ISO/IEC 25000 [3] family of standards offers a comprehensive framework for assessing and managing the quality of systems, which encompasses products and services. This framework aids in defining and evaluating quality characteristics throughout the development life cycle, ensuring that engineering projects contribute effectively to quality outcomes. Value engineering ASTM guidelines [4] define principles and steps to systematically improve the value of systems engineering by analyzing their functions and cost (as the main value variables). Nevertheless, employability and sustainability perspectives add value. Every added value evaluated by the project sponsors brings the public an especially important one. Figure 1 illustrates the potential connections between various value engineering and ISO 25000 metrics in relation to sustainability [5].

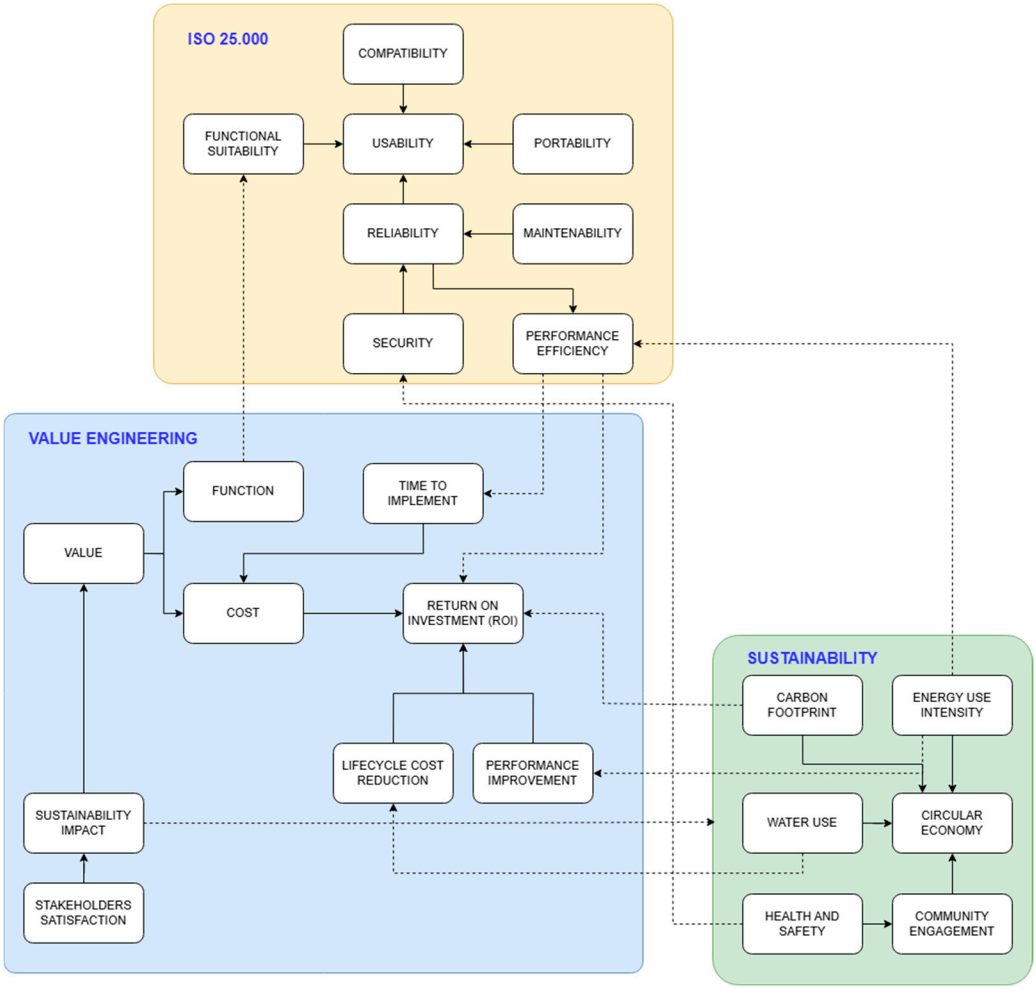



**Figure 1.** Potential metrics for program governance and the possible relationships among them.

To effectively oversee multiple engineering projects simultaneously, Program Governance (PG) must navigate the complexities associated with various interrelated metrics. This complexity can render control more expensive than engineering works. How can PG govern small engineering projects to give engineers attractive opportunities for innovation in rural areas? An intuitive answer is by automatizing data processing and using accurate definitions for engineering work products.

### *1.1. Purpose*

The following question immediately arises: how can a region like Extremadura, located in the south-west of Spain, support innovative engineering projects capable of contributing significantly to the transition of rural areas and their respective regions? In

this study, the authors propose a conceptual framework for the transformation to take advantage of the potential of engineering collectives that attempt to answer this question, particularly, and as a test case, for a region like Extremadura with approximately one million people living mostly in 10 cities (45%) and 378 villages (55%). In this region, livestock and agricultural activities play a crucial role in the economy, complemented by tourism that thrives on its rich biodiversity and historical significance. A set of European regions is listed in Table 1, with Extremadura being considered similar from both economic and biodiversity perspectives.

**Table 1.** A set of European regions. (A) identifies the minimum deviation from average. Source: EUROSTAT.

| Region (Column Identification) | Population of the Region (1) | Population Living in Cities Within the Region (2) | Population Living in Villages Within the Region (3) | Deviation from the Average of (1) | Deviation from the Average of (2) | Deviation from the Average of (3) |
|---|---|---|---|---|---|---|
| Extremadura (Spain) | 1,060,000 | 45% | 55% | −43% (A) | −6% (A) | 5% (A) |
| Alentejo (Portugal) | 730,000 | 40% | 60% | −61% | −11% | 10% |
| Peloponnese (Greece) | 577,000 | 45% | 60% | −69% | −6% (A) | 10% |
| Brittany (France) | 3,300,000 | 60% | 40% | 76% | 9% | −10% |
| Wallonia (Belgium) | 3,700,000 | 65% | 35% | 98% | 14% | −15% |
| Average | 653,500 | 51% | 50% | - | - | - |

The previous set of five regions that depend on biodiversity and tourism may account for 36% of another set, which includes nine similar regions: Andalucía, Algarve, Valencia, Toscana, Sardinia, Sicilia, East Poland, South Ireland, and Occitanie. Therefore, collaboration within the SAVE framework involving at least three different regions, including Extremadura, is essential to achieve statistical representativeness of the conclusions, exceeding 10% across Europe, in line with the standard practices of HORIZON EUROPE projects.

This framework considers job creation as a starting requirement, which can be verified through a sustainability assessment together with any environmental benefit that these engineering projects seek (e.g., GHG emission savings, water savings, improved air quality, protecting forests). Consequently, comprehensive social and environmental assessments are carried out concurrently with engineering projects. It is essential to emphasize the responsibility of large corporations towards all stakeholders in their value and supply chains. This responsibility can be effectively addressed by certifying the sustainability of the value chain [6], which is aimed at enhancing local employment opportunities. However, these large corporations, making use of the natural resources in rural areas, could finance new rural business activities or acquire their services or products to compensate for their footprints. Both employability and sustainability are regulated at a supra-regional and regional level. To complete, and improve, such governance to make it permeable to new engineering projects, the current frameworks shall adopt specific concepts or better models like the one presented here, the SAVE (Smart Agri-region Value Engineering) conceptual model.

This model consists of four themes (or paradigms) that correspond to classic agroindustry, mobility, fire prevention, and tourism, tailored to the contemporary social environment, which emphasizes ecology, safety, natural capital, and energy.

### *1.2. SAVE's Themes and High-Level Relationships*

Table 2 summarizes examples of high-level relationships between such themes in the SAVE model. It provides a first set of high-level requirements or goals for the engineering projects to be aligned to, based on the authors' experience in Extremadura.

**Table 2.** High-level relationships, goals, and requirements of SAVE. Paradigms as objects in the sentences are typed in cursive.

| **Paradigms as a Subject** | ***Paradigms as an Object*** | | | |
|---|---|---|---|---|
| | ***Ecologic Agroindustry*** | ***Mobility and Safety*** | ***Forest Fire Prevention*** | ***Energy and Tourism*** |
| Ecologic agroindustry (or eco-friendly agroindustry) | **Shall be a local agriculture using sustainable processes**. | *Shall use safe and affordable logistics for local businesses.* | *Shall avoid unnecessary deforestation or pollination depletion.* | *Shall use the same energies used in an exemplarity attitude.* |
| Mobility and safety | Shall procure safe and optimal routes for local businesses. | **Shall reduce accidents in a demographic-affected and sparse population.** | *Shall procure safe evacuation routes and solutions in case of forest fire.* | *Shall reduce accidents in a region whose economy depends on tourism.* |
| Forest fire prevention | Shall prevent forest fire from affecting business. | Shall clean forest invasion of routes. | **Shall start seeing the forest as natural capital to preserve.** | *Shall contribute to renewable energies based on biomass.* |
| Energy and tourism | Shall promote the use of local products. | Shall promote responsible mobility. | Shall promote energy saving and increase environmental safety, avoiding unnecessary use of private transport. | **Shall make renewables, no matter the size or kind, and attraction.** |

Figure 2 shows possible relationships between a first set of value engineering and ISO 25000 metrics and sustainability affecting the above-mentioned paradigms in the design stage just for the diagonally aligned sentences in Table 2. As can be seen, the potential relationships between metrics are propagated potentially to the paradigm definitions, and also related between them.

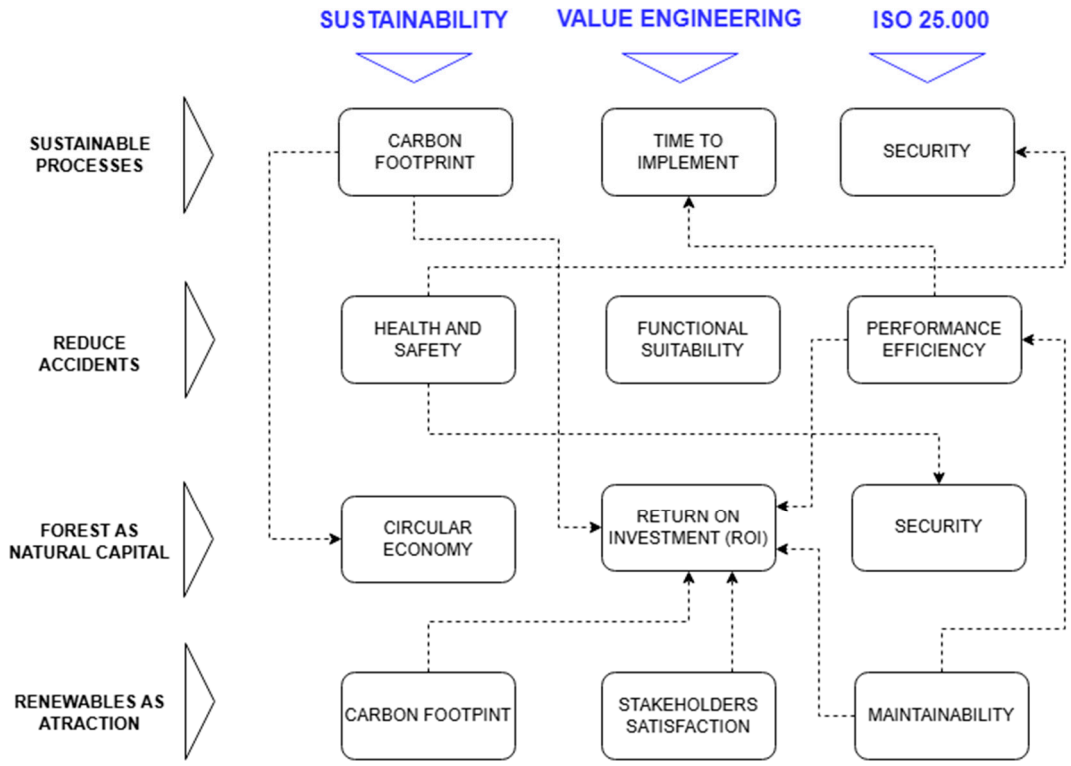



**Figure 2.** Possible metrics for SAVE program governance and possible relationships between them.

### 1.3. Key Enabling Technologies (KETs) for SAVE

Above all this, we can consider an agri-region to be smart if it adopts the methodology and tools early on and makes this an opportunity to provide valuable feedback to other regions. This can be complemented, why not, when the region's cities are on the road to becoming smart cities. In this sense, it should be noted that cities can also be spaces of creativity for engineers (e.g., in the field of rehabilitation) and that, within the city, there are vulnerabilities and common risks that need attention. It can also be assumed that the city systems are interdependent since they are driven by different organizations in charge using the same KETs and, therefore, share the need to train people and solve regulatory gaps. Here is where models and some KETS, such as Model-Based Systems Engineering (MBSE), Natural Language Processing (NLP), and Artificial intelligence (AI), can play an important role if those models can be generated quickly. Efficient communication and dissemination can be achieved by refining and validating information, ultimately saving time for those involved. Conversely, transforming models into natural language caters to individuals seeking information in text form. In this regard, initiatives such as the Immersive Realities Incubator of Almendralejo (IRIA, "Incubadora de Realidades Inmersivas de Almendralejo") [https://iriavr.es/ (accessed on 30 May 2025)] are particularly relevant. IRIA acts as a regional innovation hub that fosters the development of immersive and digital technologies, providing a valuable testing ground for KETs and visualization tools that can support both urban and rural systems under the SAVE framework. It exemplifies how a city-level infrastructure can contribute to regional digital transformation, training, and knowledge transfer by bridging engineering innovation with practical user-centered applications.

### 1.4. Engineering Disciplines for SAVE

To start aligning the engineering projects to such high-level requirements, the conceptual model introduces five engineering disciplines: communications, construction, solar energy, aeronautics, and circular economy. In this work, the authors concentrate on construction and solar energy, aiming to expand their collaboration into communications, aeronautics, and the circular economy after enhancing the methodology outlined herein. The selection of these two disciplines is based on the need for a rural area to refurbish existing constructions in compliance with construction standards and safety, the opportunity to use new and local materials, and the need to process those materials, with minimum footprints using renewables. These activities will not only be difficult to explain to decision takers for funding or permits but also to the same engineers involved, and, for this reason, the capability of transforming models (including the BIM ones) into text and text into models seems attractive and motivates this research work to find similar cases from recent research and development projects.

Regarding construction, the reuse of existing constructions [7], the validation of traditional techniques [8], the use of novel solutions in construction systems in rural areas [9], and the rehabilitation of these systems to address energy efficiency improvements entail a series of important risks that are not negligible (Eurocode 8: Design of structures for earthquake resistance; Part 3: Assessment and retrofitting of buildings). These affect both the safety of the people who inhabit them and the workers who carry out these activities during the construction phase [10]. As they are existing constructions, the structures and materials that make up these homes and guarantee their solidity are not included in the design regulations [11], as these are focused on the construction of new buildings [12]. This means that, although they are minor constructions, the technical difficulty of analyzing their safety is complex [13]. It seems that it is necessary to resort to disused standards that were the basis of their design, in addition to the fact that, given their age of construction, they may present damage or deterioration that reduce their initial conditions. If they require

consolidations or reinforcements, it means resorting to technical documents of specialized solutions [13], whose technical specifications must be clearly reflected in the project. If the consolidation solutions used are innovative, involving materials such as vegetable fiber reinforcement [14], cork residues, and straw [15], which would favor the circular economy of rural areas, a new obstacle arises [16]. These issues also pose risks for the construction phase, which must be known and assessed by the company when undertaking the work. However, this requires in-depth knowledge of solutions, materials, etc., which is generally not given in the companies that undertake these jobs, which can make them incur significant risks. In addition to the above, during the construction phase, the risks associated with workers are added. As they are unusual typologies, the worker does not know their behavior; in addition, due to time degradation, they may present damage that affects the safety of the element [17]. As an example, wooden roofs [18] may cause injuries to the people who work on them. As a solution, new technologies associate ontologies, safety, and health [19]. Technologies such as BIM applied to historic buildings (HBIM) help to manage these risks associated with materials [20,21] and occupational risks [22]. Thus, it is necessary to reduce risks and add value to the design; for this, it is essential to unite the physical components (BIM) with the processes associated with construction and their risks (MBSE) [23]. This requires specific ontologies and semantics in each aspect such as health and safety [24–26]. A further step is the integration of NLP, with important applications in project management, safety, and risk management [27], and for the improvement of knowledge [28] and safety inspections on site [29].

Regarding renewables, solar energy is the most ubiquitous and easy-to-integrate source in sunny regions. There are different types of energy systems that use solar energy on an industrial scale, but we can simply differentiate between solar thermal and electrical systems, and, among the latter, photovoltaic systems. Regarding industrial processes that may be related to the processing of construction materials from agriculture or forestry, wood drying is well known, along with solar thermal use (e.g., [30,31]) and cork blending with solar steam [32]. For both drying and steam production, medium-temperature solar thermal systems can provide a solution to reduce the carbon footprint of the processes. Solar energy systems have, like other installations, a design process that uses geometries and thermal and fluid modeling for the sizing of the collector elements and heat distribution networks and the control to supply the heat in the quality and quantity demanded. The design of the system may also eventually involve the sizing of support structures or structural reinforcements. Subsequently, like any thermal system, it must be installed, commissioned, and maintained correctly during its useful life. All these activities are, for the moment, dependent on suppliers and installers, with no standard yet existing, which puts the continuity of use of the installation at risk if these companies stop operating in the market. For these purposes, good practices can be applied to the procurement of goods and services by public administrations [33], such as the obligation to provide the BIM model required for construction works, but also the models and configuration of controls in the case of public funding.

Systems engineering is a young discipline that combines with different engineering disciplines and System of Systems (SoS) approaches. In this regard, digital solutions are being used for configuration management, a process shared by both systems engineering and asset management disciplines [34,35], among others, whose respective processes are described in ISO 15288 [36] and ISO 55000 [37], respectively. Implementing systems engineering practices [38] is feasible and is currently under consideration for power systems [39]. Configuration management can be enhanced to encompass systems integration that involves multiple verification and validation actions [40]. This is essential as the solar heat generation system must be integrated with autoclaves, ovens, or dryers, and with backup heating

systems such as combustion chambers or boilers. Another system engineering practice, Model-Based Systems Engineering (MBSE), uses models to support the entire life cycle of a system, including requirements management, verification, validation, and other processes, enhancing communication and collaboration, but also assessing the impact of the designs before building them, promoting early integration and sustainability in general [41].

### *1.5. Research Objectives (KETs) for SAVE*

This work has high-level objectives related to detecting R&D and innovation experience on solar energy and construction, and advances in MBSE-AI-NLP for smart governance to be used in regions like Extremadura.

## 2. Materials and Methods

Figure 3 illustrates the research workflow, where the milestones signify the achievement of partial results (primarily presented as tables). The rectangles denote various sections, while the circles represent the starting and ending milestones, respectively. An explanation follows.

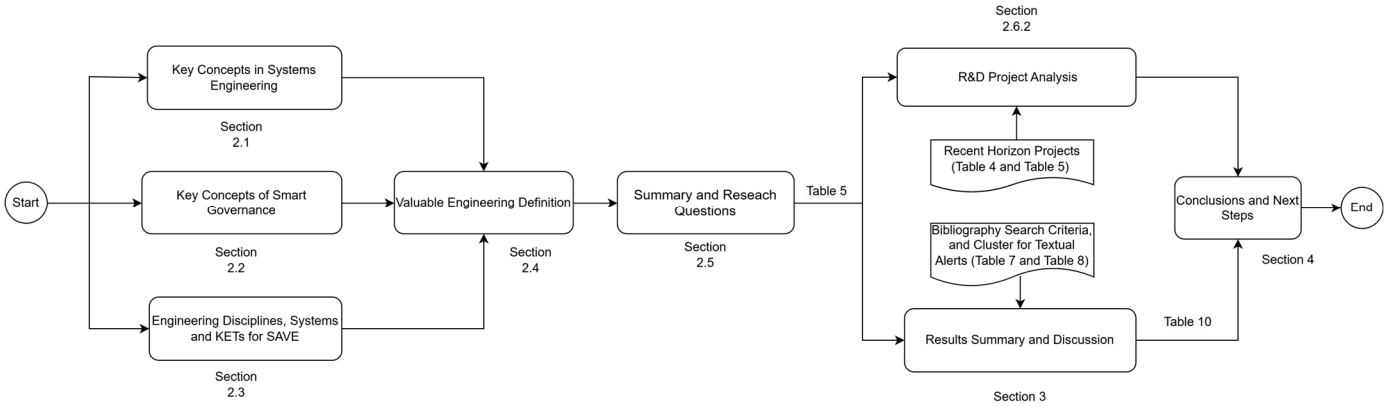



**Figure 3.** Research workflow.

In Section 2.1, the authors introduce and substantiate key concepts of systems engineering. After this, Section 2.2 provides definitions and trends in smart governance. In Section 2.3, the authors introduce the engineering disciplines and systems, focusing on a rural and agri-region like Extremadura. This section also introduces the use of key technologies by such systems and the possible relationships between them, defining the resulting SAVE as a System of Interest (SoI). After that, Section 2.4 introduces a definition of smart agri-region value engineering, including definitions for measuring and verifying the contribution of new engineering projects during the current ecological transition. In Section 2.5, the authors provide a summary and research questions in line with the high-level objectives.

Section 2.6 discusses European R&D and innovation programs, highlighting results and findings from specific projects focused on solar energy and construction. To this end, there have been recent calls from the Horizon Europe Program. Section 2.7 provides evidence from research works that have been sufficiently assessed and describes textual evidence extraction and validation methodology. An attempt is made to answer specific research questions (about MBSE-NLP-AI and data quality in smart governance), using databases of recent publications from the ScienceDirect repository, whose results and findings are within this subsection. The tables that define the search process are arranged as complementary information to the publication so as not to divert the reader's attention from what is relevant, which is referenced in a key diagram of the related process.

This paper concludes in Section 3 with a subsection on the summary of results and discussion, and in the final Section 4 with conclusions and next steps.

### 2.1. Key Concepts of Systems Engineering

In this section, the systems engineering methodology [38] is introduced as an enabler of quality engineering; that is, it is traceable and verifiable, which ideally avoids avoidable errors. It is an engineering technology that covers the entire life cycle, from the concept to the dismantling of the system, understanding that any product or service that is born in the rural area requires systems to produce it. In real environments, systems are often exposed to common risks or may induce risks against one another. Conversely, they can also serve as solutions to mitigate those risks. Given the intricacies involved, there emerges a pressing necessity to embrace a System of Systems (SoS) approach, wherein each system will possess its own life cycle [42]. However, there are common elements and relationships whose life cycles must be managed in parallel. This approach requires considering a specific System of Interest (SoI) and being able to accurately communicate between the different engineering organizations and disciplines. For this, it would be helpful to use Model-Based Systems Engineering (MBSE) and to generate models with Artificial Intelligence from natural language anytime, on demand.

### 2.2. Key Concepts of Program Governance

Theoretical governance must effectively align engineering actions with regional, national, or European development objectives as appropriate. It should facilitate dialogue between all stakeholders, enable informed decision making, and ensure accurate measurement and verification. Consequently, it necessitates the availability of open data for the System of Interest (SoI). In this context, the governance model outlined appears to align closely with the practices already employed by smart cities. The aforementioned statement suggests that it is feasible to establish metrics for assessing and verifying the role of engineering in the transition of agricultural regions. Additionally, it raises the important issue of data quality management within the governance frameworks of smart cities. Notably, INCOSE's Working Group on Smart Cities [43] has already provided definitions and initial insights regarding the integration of artificial intelligence in this domain. It seems illogical to apply different methodologies for governing a city, a region, or an innovation program. Instead, it is essential to utilize appropriate metrics tailored to each purpose and to automate processes wherever possible.

### 2.3. Engineering Disciplines, Systems, and KETs for SAVE

In this section, the authors, who are experts in their fields, offer detailed descriptions of the previously mentioned disciplines as they pertain to the region of Extremadura in Spain. These insights are also largely applicable to other rural areas. Each description is thoroughly analyzed in Section 2.3.4, culminating in the definition of the SAVE model.

#### 2.3.1. Communications and Services

Digital communications play a crucial role in shaping the future of rural areas by fostering economic growth, driving innovation, promoting social inclusion, and mitigating the challenges of remoteness.

Nowadays, due to digital technology divides between urban and rural regions, advanced connectivity solutions have become essential for fostering smart rural environments, ensuring equitable access to information, services, and opportunities. The integration of Key Enabling Technologies (KETs), such as Artificial Intelligence (AI), the Internet of Things (IoT), digital twins, blockchain, and cybersecurity [44–46], is transforming rural ecosystems by enhancing productivity, governance, and resilience. One of the most impactful

applications of digital communications in rural areas is innovation in social ecosystems. High-speed networks and edge computing allow real-time remote collaboration, e-learning, and telemedicine, which are crucial for improving healthcare and education in isolated and remote regions. AI-driven predictive analytics further support rural policymaking, enabling data-driven decision making to optimize resource allocation and infrastructure planning.

From an industrial and agricultural perspective, IoT, digital twins, and remote sensing are redefining precision farming, environmental monitoring, and supply chain management. Remote sensing, in particular, plays a crucial role in rural development by enabling real-time data acquisition through satellite imagery, instrumented drones, and ground sensors, allowing for optimized resource allocation, early detection of crop diseases, and efficient water management [47–49]. Furthermore, robust digital communications infrastructure is essential to ensure seamless data transmission and service accessibility, fostering economic growth and preventing rural depopulation by creating new opportunities for smart agriculture, sustainable land management, and rural entrepreneurship. Sensors deployed in rural landscapes collect real-time data on soil conditions, crop health, and weather patterns, feeding Artificial Intelligence (AI) models that optimize agricultural outputs while minimizing environmental impact. Blockchain technology, in turn, ensures transparent and secure transactions, enabling decentralized traceability of food production and distribution while strengthening trust among stakeholders. However, the adoption of these disruptive technologies also brings challenges, particularly regarding cybersecurity. Rural infrastructures are increasingly vulnerable to cyber threats due to their growing reliance on digital services. The integration of AI-powered security frameworks and blockchain-based authentication mechanisms can mitigate these risks, safeguarding critical infrastructures, agricultural supply chains, and rural e-governance systems. In this context, KETs serve as the backbone for an intelligent, secure, and sustainable transformation of rural areas. The convergence of next-generation communication networks with AI, IoT, digital twins, cybersecurity, and blockchain represents a strategic opportunity to develop resilient rural economies and smart social ecosystems, ensuring that rural populations benefit from the same technological advancements as their urban counterparts.

In Spain, and particularly in the region of Extremadura, digital connectivity is becoming a cornerstone for rural development. With over 60% of the population living in rural areas, ensuring high-speed internet access is crucial for fostering economic growth, digital inclusion, and social cohesion. In recent years, the fiber-optic infrastructure has expanded significantly, reaching more than 90% of the rural population, enabling citizens and businesses to access high-speed broadband services. This progress lays the foundation for the next wave of connectivity: 5G and future 6G networks, which will further revolutionize economic activities, smart agriculture, and digital public services. The deployment of 5G and 6G technologies will have transformative effects on rural economies by enabling Ultra-Reliable Low-Latency Communication (URLLC) and massive IoT connectivity. These advancements will allow rural businesses to integrate AI-driven automation, smart logistics, and real-time data analytics, fostering Industry 4.0 applications in agri-tech, renewable energy, and eco-tourism. Moreover, these networks will be key to preventing and reverting rural depopulation, offering young professionals and entrepreneurs the opportunity to develop digitally driven businesses without the need to migrate to urban areas. The convergence of fiber-optic broadband, 5G, and emerging 6G technologies will enhance remote working conditions, digital education, and e-governance, this way making rural environments more attractive for future generations. By integrating Key Enabling Technologies (KETs)—including Artificial Intelligence (AI), blockchain, digital twins, IoT, and cybersecurity—rural Spain is positioning itself at the forefront of digital transformation. These advancements will not only boost local economies and modernize

agriculture but also establish sustainable intelligent rural environments that are resilient to economic and demographic challenges. The expansion of next-generation networks in Extremadura and other rural regions is therefore not just an infrastructure upgrade, it also represents a fundamental shift towards a more connected, innovative, and competitive rural ecosystem. The deployment of LoRaWAN (Long-Range Wide Area Network) antennas in rural areas represents a game-changer for IoT connectivity in agriculture and livestock management. Unlike traditional cellular networks, LoRaWAN operates on unlicensed frequency bands, making it a cost-effective and scalable solution for enabling long-range low-power communication across vast rural landscapes. By installing non-licensed LoRaWAN antennas, rural communities can establish autonomous IoT networks, fostering digital transformation without depending on expensive infrastructure investments from major telecom operators. In agriculture, LoRaWAN technology enables real-time monitoring of soil moisture, weather conditions, irrigation systems, and crop health, not neglecting alarms for meteorological menaces. This will allow farmers to make data-driven decisions that optimize water usage, increase productivity, and reduce environmental impact. Smart farming applications using LoRaWAN also include autonomous pest detection, predictive disease modeling, and automated machinery tracking, enhancing operational efficiency and sustainability. For livestock management, LoRaWAN provides real-time geolocation tracking, health monitoring, and environmental control for farm animals. IoT-enabled wearable sensors can detect temperature fluctuations, movement patterns, and feeding behaviors, helping farmers prevent diseases and improve livestock welfare. The wide coverage and low energy consumption of LoRaWAN technology makes it ideal for remote pastures, where cellular connectivity is often limited or nonexistent. Integrating LoRaWAN with AI, blockchain, digital twins, and cybersecurity further enhances precision agriculture, smart irrigation, and automated livestock monitoring, reducing operational costs and increasing rural sustainability. By fostering an ecosystem of IoT-enabled rural connectivity, LoRaWAN networks will play a crucial role in the evolution of rural areas, ensuring that agriculture and livestock industries remain competitive in the digital era while supporting the long-term viability of rural communities.

#### 2.3.2. Construction

In the application area, herewith the region of Extremadura, construction systems based on stone, wood, and adobe are expected. Geometrically, they present irregularities that sometimes make their analysis complex, along with interrelationships with the neighboring ones. The application of BIM technology to create models from point clouds [50,51] allows improving context analysis and neighboring risks. These risks are widely known and cataloged by extensive experience, so their connection with NLP would provide an important advantage in their analysis. The vertical structural elements are usually masonry or adobe walls on the ground floor, while, on the following floors, there are wooden frames with adobe filling. These materials provide structural solidity and good thermal insulation and inertia, but they are solutions that are not within those recognized by current regulations. The horizontal and covering elements are generally half-timbered with wooden decking. The roofs are inclined with a certain slope as they are areas with significant snow loads depending on the altitude. Structurally, the roofs are made of round wood, supported by the walls and beams on the ridge. Technologies such as BIM and HBIM [20,52,53] provide great value in the structural analysis of horizontal and vertical elements by being able to incorporate information on the state of conservation of the elements. This can enrich analysis with information on damage ontology and occupational risks, which, through Natural Language Processing (NLP), improves decision making. For analysis of energy efficiency, the creation of reliable envelopes of reality and their simulations in BIM [54,55] provides

added value in decision making, where it is possible to integrate, in addition to the energy behavior, the constructive solutions and the occupational risks associated with them. This also considers the state of conservation of the elements, and the creation of HBIM models that collect damages, known and cataloged, which would improve decision making.

From the reliable integration of the built reality in HBIM [56], it is possible to carry out the most precise numerical simulations required by the introduction of innovative solutions for structural or energy rehabilitation [54]. Once the different risks are known and analyzed, integration into the BIM AI and NLP models would allow the generation of documentation, requirements, and contracts consistent with the built reality.

#### 2.3.3. Solar Energy

Extremadura owns a large annual solar resource of 5.7 kWh per day [57]. Solar Photovoltaics (PV) is a very flexible and modular renewable energy electrical power supply that can be distributed with various topologies. It can be individual, community concentrated, and even from a regional power station. This way, PV is very appropriate for a mostly agricultural region like Extremadura, where the electrical grid is not in any measure dense, except in the main cities. In Extremadura, there are 14 regional PV powerplants connected to the national grid, amounting to almost 3 GW, including Europe's biggest one. They are capable of supplying the average consumption of homes of their entire population by production alone. Some of them already incorporate a small amount of backup batteries for several hours of nominal power storage. But fully supporting the development of sustainable sparse communities is not possible nowadays because of the large dispersion of their low-density population of 25 inhabitants/km$^2$. Moreover, there are some areas of much lower density, such as the Siberia Extremeña with 9 inhabitants/km$^2$. They include wild, wooded, and humid landscapes, also hosting the largest areas of inland lakes in the region. Agriculture is difficult because of poor soil, thus the deployment of extensive land use of solar energy is promising. Thermal wild biomass is abundant, but its exploitation is mostly restricted to individual house heating and some minor additional applications [58].

Nowadays, photovoltaics can drive affordable heat pumps to supply heat at moderate temperatures, called low-to-medium temperature industrial heat <150 °C, and to supply cold for acclimatization or perishable crop storage. This includes dwelling and hostel acclimatization, crop air drying, and mineral preparation, among others. Higher temperatures are only reachable using thermo-solar technologies using solar concentration [59]. Both heat pumps and solar thermal technologies are appealing options for water heating. However, solar thermal systems have the advantage of operating independently of electric connections, thereby reducing the risk of fire in natural habitats or forested areas. They provide hot sanitary water and can also be utilized for indoor space heating.

In any of these technologies, energy storage is relevant. Long-lasting batteries are required when electrical storage is preferred. As an alternative, Thermal Energy Storage (TES) is demanded. This resource is typically characterized by a lesser impact on natural resources compared with batteries, and reduced end-of-use residues. This is largely due to the use of recyclable materials, such as iron, aluminum, and similar substances; actually, they can be part of the circular economy. The intelligent management of a hybrid energy system, probably including intelligent smart micro-grids, TES, and energy backups, would be another client for the development of advanced digital networks, as described above. Green solar hydrogen can replace batteries, offering longer storage life, and is inter-seasonal and can boost portability.

Regarding KETs, BIM is already being used in the building sector [60] and is expected to be used for industrial solar since the large concentrating solar plants are already progress-

ing in dynamic modeling for systems integration [61], and LoRa networks are increasingly in use for energy too.

The important fact is that the region of Extremadura has plenty of space for the deployment of solar energy, either clustered or distributed. Wind energy can plug into the system, when available, and solar greenhouses can convert any rural region into a competitive agri-region too.

#### 2.3.4. Aeronautics and Air Transport

The availability of a regional airport facilitates aero works, but investment and current costs are large, only justified by a circumstantial effect, such as substantial tourism or industry activity. In particular, wide natural resources, such as the ones in Extremadura, and similar regions abroad, can drive ecological and nature-oriented tourism coming from out of the country. The massive amount of traffic that can be involved cannot happen or can be determined as non-desirable for its expected impact on nature. In contrast, sustainable hunting/nature observation and similar tourism are of high value, incorporating much less traffic and are coincidental with environmental care. It can be embraced by less impacting air transport, even large electrical drones, which are actually non-human-piloted small aircraft, and robots, still to come but with promising examples. Sharing an advanced digital communication network, such as the one described above, is essential for such an air system. Pilot experiences will orient future appropriate technologies to apply. Such a low-investment air transport architecture is multipurpose, as it can support sanitary assistance and low-weight merchandise delivery, thus serving the population in rural Extremadura as it does not need a fixed infrastructure other than some air bases. Last but not least, such an aerial remotely piloted squadron will boost control for fire menaces, detection, and fight. People's safety and security will also be reinforced because the adaptation requires more policymaking addressing concerns about privacy, noise, and other societal impacts [62].

The use of battery-propelled small-size aircraft coincides with terrestrial and even river transport using electric vehicles as they can be supplied with shared photovoltaic and battery infrastructures [63]. This infrastructure smoothly integrates with the systems described herewith.

#### 2.3.5. Circular Economy

The circular economy is a relatively modern discipline. This economy is based on the classic sector-agnostic four Rs hierarchy: reduce, reuse, recycle, and recover. By reducing, in the context of this work, we mean avoiding consuming what is not essential and being able to reuse what others do not use, for which communications are currently essential in both rural and urban areas, although, in rural areas, it is possible to facilitate the exchange of goods in public square markets. By recycling, we mean our ability to recover certain parts of a product and give them another use, which is not always possible without creative spaces, but, fortunately, the rural area usually attracts capable artists and craftsmen in addition to attracting tourism that is more sensitive to these issues. By recovering, we refer to raw materials and the energy (as fuels) of some materials, and this is where industrial processes can eventually generate employment. It is also possible to talk about the nine sector agnostic hierarchy [64].

The industrial processes related to the circular economy can be more ecological if they use renewable energy, such as solar energy, lower emissions logistics, or even an optimal combination. It can be also considered that harvesting forest biomass is a type of circular economy by which the collected biomass can be converted into energy to provide heat to homes and industries, such as agribusiness, while protecting the forest mass from

fires [65]. Forest firewood cropping could eventually benefit both homes, industries, and communication routes, creating jobs [66].

Examples of industrial processes for the use of this biomass energy are cleaning with hot water, torrefaction, drying, and pellet manufacturing, Another type of circular economy typical of rural areas is that of postharvest food preservation. For example, crops dried on time reduce losses. These drying processes are part of the agribusiness value chain, ideally using solar solutions as mentioned above. For example, correct drying allows industrial hemp fibers to be valid for composites pieces (furniture, shells) [67].

#### 2.3.6. SAVE as a System of Systems (SoS)

In relation to KETs, from the point of view of the aforementioned authors, there are BIM, IoT, AI, and drones, in approximately 83% of the mentioned systems. In the published statistics, the use of technologies such as digital twin, resulting from the composition of other KETs, has also been considered. Regarding alignment with the objectives indicated in Table 1, 69% of them seem to be shared by several disciplines, while the other 31% seem to be specific to one discipline, according to the authors. These quick statistics, along with the relationships illustrated in Table 3, reinforce the notion of approaching the transition of rural areas through a System of Systems (SoS) framework [42]. Consequently, it is logical to also map the SoS characteristics in Table 4 to support this assumption, at least on a preliminary basis.

**Table 3.** Discipline and paradigm relationships summary after experts' description of disciplines.

| **Paradigms** | **Disciplines** | | | | |
|---|---|---|---|---|---|
| | **Communications and Services** | **Building/ Construction** | **Solar Energy** | **Aeronautics** | **Circular Economy** |
| Ecologic agroindustry (or eco-friendly agroindustry) | | *Wood, stone, and adobe use.* | *They can be part of the circular economy.* | | *The circular economy can be more ecological if they use renewable energy, such as solar energy, a lower emissions logistics, or even an optimal one.* |
| Mobility and safety | *Smart logistics: digital communication network, such as the one described above, is essential for such an air system.* | | | *It can be embraced by less impactful air transport; people's safety and security will be also reinforced.* | |
| Forest fire prevention | *Environmental monitoring* | | | *Remotely piloted squadrons will boost fire menace and detection.* | |
| Energy and tourism | | *Good thermal insulation* | *Heat pumps for dwelling and hostel acclimatization* | | *Harvesting forests and protecting the forest mass from fires could also reduce tourism that seeks to enjoy the green areas.* |

A System of Systems (SoS) comprises systems with at least two conditions: operational independence, managerial independence, geographical distribution, emergent behaviour, or evolutionary development processes, according to SoS definitions.

Figure 4 illustrates the themes and framework outlined in the preceding sections. Notice that the dashed lines correspond to the high-level requirements explained previously and that the continuous arrows are just a set of relationships from Table 2, representing also other potential relationships (conflicts, synergies) between the paradigms given by the objectives of Table 1. It is important to note that there are two "use" relationships that have

yet to be verified by the authors (presumably experts) and necessitate further collaborative research in Section 2.6.

**Table 4.** System and SoS characteristic mapping.

| System | Operational Independence | Managerial Independence | Geographical Distribution | Emergent Behavior or Evolutionary Development Processes |
|---|---|---|---|---|
| Communications | In general, the related systems are operated by different businesses | Use different communication solutions in general | Yes | Massive IoT use may require reinforcing communications and AI capabilities. |
| Aeronautics | | | Yes | UAVs may find limits of memory in long periods without civil communications. |
| Construction | | Absolutely independent | Yes | BIM driven by NLP instances, manufacturing order driven by BIM models. |
| Circular Economy | | Solar energy installers are normally hired by industrial activities | Yes | High demand for biomaterials may require adapting more crops with enough time. |
| Solar Energy | | | Yes | Energy storage could make using bioenergy unnecessary. |

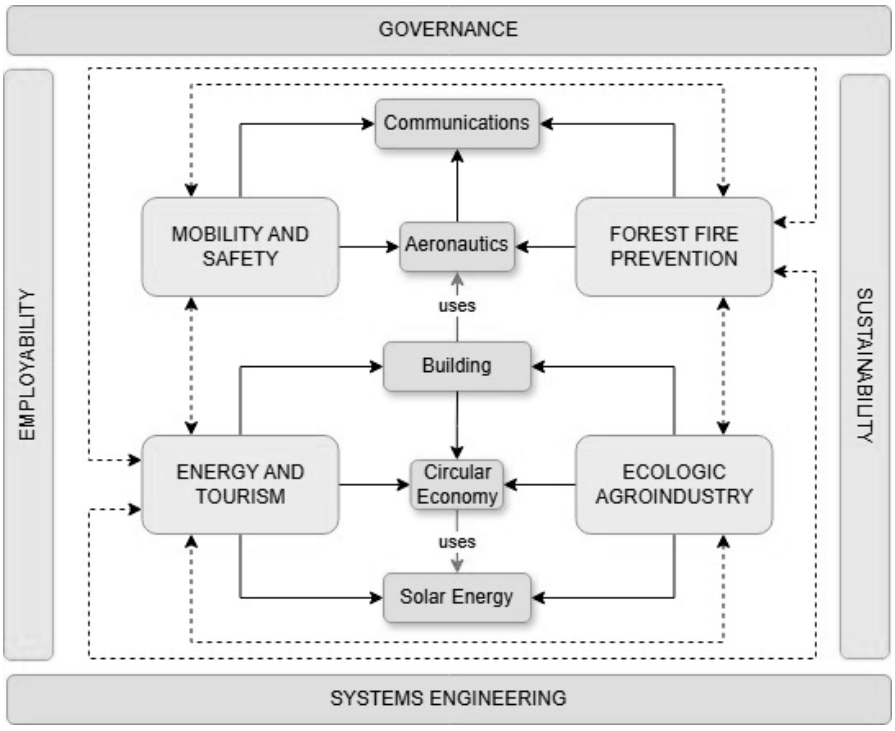



**Figure 4.** SAVE conceptual model. The arrows represent relationships, and the rectangles represent concepts.

The framework defines the type of objectives (employability or educational, environmental, economic, and societal), but other objectives could be related to the new systems (such as common KETs). It is important to note that governance is positioned at the top of the framework, responsible for ensuring alignment with regional paradigms. This means that regional employment plans, developed in accordance with regional procedures, along with compliance on sustainability—whether voluntary or mandatory—must be reported to a designated supervisory entity to secure funding or obtain necessary permits [68]. The SAVE model states that the engineering work products (of high-impacting systems) shall be reported too, and for this, systems engineering [38] is presented as an enabling method-

ology allowing such reporting by using systems engineering ITs [69], motivating research to detect possible trends regarding MBSE-NLP-AI in Section 2.7 for smart governance.

### *2.4. Smart Agri-Region Value Engineering Definition*

Considering the aforementioned points, it is posited that a preliminary definition of value engineering can be established as the engineering activities associated with a system designed to foster the development of a smart agricultural or rural region. This system aims to provide relevant reports to a specified administrative level regarding employment, sustainability, and systems engineering initiatives. Regarding the systems engineering plan, by providing not only documents or certifications but also other detailed engineering work products such as requirements, models, verification actions, risks, and opportunities to enable regional program governance to use new tools and methodologies like Artificial Intelligence (AI) and for smart governance. A way to achieve this is to provide MBSE-AI-NLP tools for such work products to be communicated as models, avoiding the inconveniences and cost of performing it manually and normalizing some views that systems engineering delivers value for non-engineers. Is this possible?

The provision of engineering information must safeguard intellectual property rights, provided that the tools and methodologies adhere to these rights while also considering public interest. This involves mitigating risks and leveraging emerging opportunities associated with knowledge reuse and the timely adaptation of the educational system.

Since this kind of governance is quite new and is not extended to all engineering disciplines, those engineering entities open to report this way may benefit from grants for contracting systems engineering advisory services, enabling ITs, specific training, or public recognition. For safety critical systems, it would be mandatory to demonstrate engineering due diligence in ensuring further certification for costly and highly granted systems, avoiding extra cost and delaying risks in general. The concept of smart agri-region value engineering is useful also for some countries on their road to escaping from the "middle-income trap" by adopting technologies coming from abroad to use them domestically and invest in engineering [70]. Sharing an ontology for SAVE would facilitate a deeper understanding of various disciplines and their interactions [71]. Additionally, it could serve as a foundation for effective technological collaboration and further due diligence certification by professional engineering associations.

### *2.5. Summary and Research Questions*

This work establishes two types of research questions, the ones corresponding to recent experience in R&D projects that are related to connected themes or disciplines, and the ones related to current advances in MBSE-AI-NLP for smart governance. Table 5 shows the correspondence of the questions (Q) with the conceptual model relationships, the main assumptions, the strategy to answer the questions, and the high-level objectives.

**Table 5.** Question correspondence to the model's relationships, assumptions, and objectives.

| High-Level Objectives | Question | Conceptual Model's Relationships | Assumption | Strategy |
|---|---|---|---|---|
| Find examples where new aeronautical applications (UAVs, drones) are being used for building. | (Q1) Is aeronautics being used for building? | Building requires aeronautics. | UAVs and drones can be operated in any agri-region with a minimum infrastructure. | Recent R&D and innovation projects and expert analysis using categories. |
| Find examples where solar energy systems are being used for circular economy. | (Q2) Is solar energy being used for circular economy? | Solar energy can be used by circular economy. | Solar energy systems save GHG and provide local heat to several industrial processes also in use in the circular economy. | |

**Table 5.** *Cont.*

| High-Level Objectives | Question | Conceptual Model's Relationships | Assumption | Strategy |
|---|---|---|---|---|
| Find interesting trends in MBSE-NLP-AI for SAVE. | (Q3) Is MBSE-NLP-AI being used in open innovation environments? | Systems engineering is part of the framework. | MBSE is related to systems engineering. | Bibliographic research and Natural Language Processing (NLP), and expert analysis. |
| | (Q4) Is MBSE-NLP-AI being used for risk management? | Sustainability is part of the framework. | MBSE allows mapping risks in a more continuous manner. | |
| | (Q5) Is MBSE-AI-NLP being used for program governance? | Governance is part of the framework. | Governance requires quality data from sparse sources. | |

### *2.6. Search for Evidence in R&D and Innovation Programs*

The purpose of the search for evidence in R&D projects is to find examples of questions Q1 and Q2 on the use of drones in construction and the use of solar energy for the circular economy for SAVE.

#### 2.6.1. R&D Project Search

The authors conducted a first search of European Commission-funded Research and Development (R&D) projects to detect the current trends considering the use of drones in building and the use of solar energy for the circular economy. The public CORDIS database was used to search for projects from Horizon 2020 and Horizon Europe programs using the following criteria:

- 'DRONE*' AND 'BUILDING' (Q1)
- 'CIRCULAR ECONOMY' AND 'SOLAR ENERGY'(Q2)

Tables 6 and 7 show the results.

**Table 6.** R&D projects for Q1 (with literal contents).

| ID | Name | Summary | End Date |
|---|---|---|---|
| 774094 | STARDUST | *The objective of the STARDUST project is to pave the way towards the transformation of the carbon supplied cities into Smart, highly efficient, intelligent, and citizen citizen-oriented cities, developing urban technical green solutions and innovative business models, integrating the domains of buildings, mobility, and efficient energy through ICT, testing and validating these solutions, and enabling their fast roll out in the market.* | 31 Mar. 2024 |
| 637221 | Built2Spec | *Built2Spec brings together a new and breakthrough set of technological advances for self-inspection and quality assurance that will be put into the hands of construction stakeholders to help meeting EU energy efficiency targets, new build standards, and related policy ambitions. B2S will expand upon a cloud based construction support platform, conceived following the most advanced integrated design and delivery framework for the building sector and hosting applications that facilitate worksite activities and quality compliance by putting knowledge in the hands of contractors.* | 31 Dec. 2018 |

**Table 6.** *Cont.*

| ID | Name | Summary | End Date |
|---|---|---|---|
| 665066 | DigiArt | *The 3D data captured by the scanners and drones, using techniques such as laser detection and ranging (LIDAR), are processed through robust features that cope with imperfect data. Semantic analysis by automatic feature extraction is used to form hyper-links between artefacts.* | 30 Nov. 2018 |
| 644271 | AEROARMS | *AEROARMS proposes the development of the first aerial robotic system with multiple arms and advanced manipulation capabilities to be applied in industrial inspection and maintenance (I&M).* | 31 Aug. 2019 |
| 871479 | AERIAL-CORE | *The EU-funded AERIAL-CORE project is developing an integrated aerial cognitive robotic system to assist human workers in inspection and maintenance activities. Specifically, it will integrate aerial robots for long range (several kilometres) and very accurate (subcentimetre) inspection of the infrastructure capability.* | 30 Nov. 2023 |
| 823987 | RESEARCH | *The EU-funded plans to introduce a multitask platform that utilises remote sensing technologies applied with geographic information systems to map and monitor cultural heritage sites. To start, researchers assessed the intensity of a threat using different types of satellite and ground data, along with data acquired using UAVs. This These data was were then analysed analyzed and used to map the various hazards facing an archaeological site or feature. The project also used aerial and terrestrial remote sensing data, including data collected* via *ground-penetrating radar (GPR), to detect and map both the standing structure itself and its subsurface archaeological features.* | 31 Oct. 2023 |
| 857031 | 5G!Drones | *The 5G!Drones project will run trials on several unmanned aerial vehicles (UAVs) to prove that 5G infrastructure can support the simultaneous running of three types of UAV services, using network slicing.* | 30 Nov. 2024 |

**Table 7.** R&D projects for Q2 (with literal contents).

| ID | Name | Summary | End Date |
|---|---|---|---|
| 816336 | SUNRISE | *The Coordination and Support Action (CSA) SUNRISE is a scientific and technological project ambitious in its goal to exploit solar energy and atmospheric gases such as $CO_2$, water and nitrogen to provide a sustainable alternative to the fossil-based, energy-intensive fuels and compound chemical synthesis process by using a Large Scale European Research Initiative (LSERI) to secure the supply side of the circular economy with a pipeline of disruptive technologies for manufacturing renewable fuel, chemicals, fertilizer, and hydrogen from atmospheric $H_2O$, $N_2$, and $CO_2$ at high yield with up to 2500 ton/ha.yr $CO_2$ sequestration.* | 30 Abr. 2020 |
| 681292 | FANOEC | *The oxygen evolution reaction (OER) is the key reaction to enable the storage of solar energy in the form of hydrogen fuel through water splitting. Efficient, Earth-abundant, and robust OER catalysts are required for a large-scale and cost-effective production of solar hydrogen. FANOEC's team of researchers has been able to achieve a deep understanding of OER on metal oxides at the molecular level, and to develop better catalysts based on this understanding.* | 30 Jun. 2021 |
| 679814 | SOLENALGAE | *The ERC-funded SOLENALGAE project probed the molecular basis for efficient light energy conversion into chemical energy, in order to increase the biomass production in microalgae, by investigating the principles of light energy conversion with biotechnological engineering of algal strains. The project applied new processes improving photosynthesis, enabling novel food, feed, and health products while also driving progress towards sustainable biofuels.* | 31 Aug. 2021 |

**Table 7.** *Cont.*

| ID | Name | Summary | End Date |
|---|---|---|---|
| 639233 | COFLeaf | *The EU-funded COFLeaF project developed a single-site heterogeneous photocatalytic system that can reliably generate solar fuels from water and $CO_2$. Specifically, it will integrate various subsystems required for the overall photocatalytic process into a polymeric platform called the 'COF leaf'.* | 31 Aug. 2020 |

#### 2.6.2. R&D Project Analysis

Regarding Q1, projects providing evidence in the deliverables about considering use cases in rural areas are AERIAL-CORE (power lines), RESEARCH (archeologic heritage), and 5G!Drones (forest fire detection). Regarding Q2, projects providing evidence in the deliverables considering industrial processes in a circular economy are SOLENALGAE (alimentary, health, bioenergy), and COFLeaf (biopolymers, biogas). It can be concluded that there is a potential lack of projects in rural areas dealing with drones and that solar energy for the circular economy might also require more specific projects. After that, further analysis about the motivation for engineering to work in such areas could be performed to verify the main assumption contextualizing this research. Despite not being used specifically in rural areas, the techniques can be valid for rural areas.

### *2.7. Search for Evidence in Recent Research Works*

The purpose of the search for evidence in recent research consortiums was to find trends regarding questions Q3, Q4, and Q5, on the use of MBSE-AI-NLP for SAVE. To achieve this, extensive research was been conducted using a comprehensive scientific and technological database, employing the necessary methodologies. ScienceDirect™, Amsterdam, The *Netherlands* (search portal) was chosen to search for research readings. The textual alerts were implemented using a Natural Language Processing (NLP) method that looks for textual evidence. Acting as experts, the authors verified the degree of interest for each work in each question to confirm the gap. Finally, the most exciting works were analyzed to find potential improvements for the model. This method has been described and validated in [71–75] and it is represented in Figure 5 where the following Table 8. Tables 9–11 of this document have been allocated.

**Table 8.** Bibliography search criteria and cluster for textual alerts.

| Concept | Metadata and Operators (For the Search Portal) | Keywords (For Textual Alerts) | <Cluster> (For Textual Alerts) |
|---|---|---|---|
| OPEN INNOVATION | ('Model-based' OR 'systems engineering') ---------- ('artificial intelligence' AND 'natural language processing' AND 'automatic transformation') | Open innovation, innovation | Collaboration, business, market, technology, supply, value, chain, dynamic, model |
| RISK MANAGEMENT | | Risk management, risk | Risk, management, opportunity, event, probability, impact, exposure, model, method |
| PROGRAM GOVERNANCE | | Governance, govern | Program/programme, public, private, data, quality, open data, process, target, objective, plan, policy |

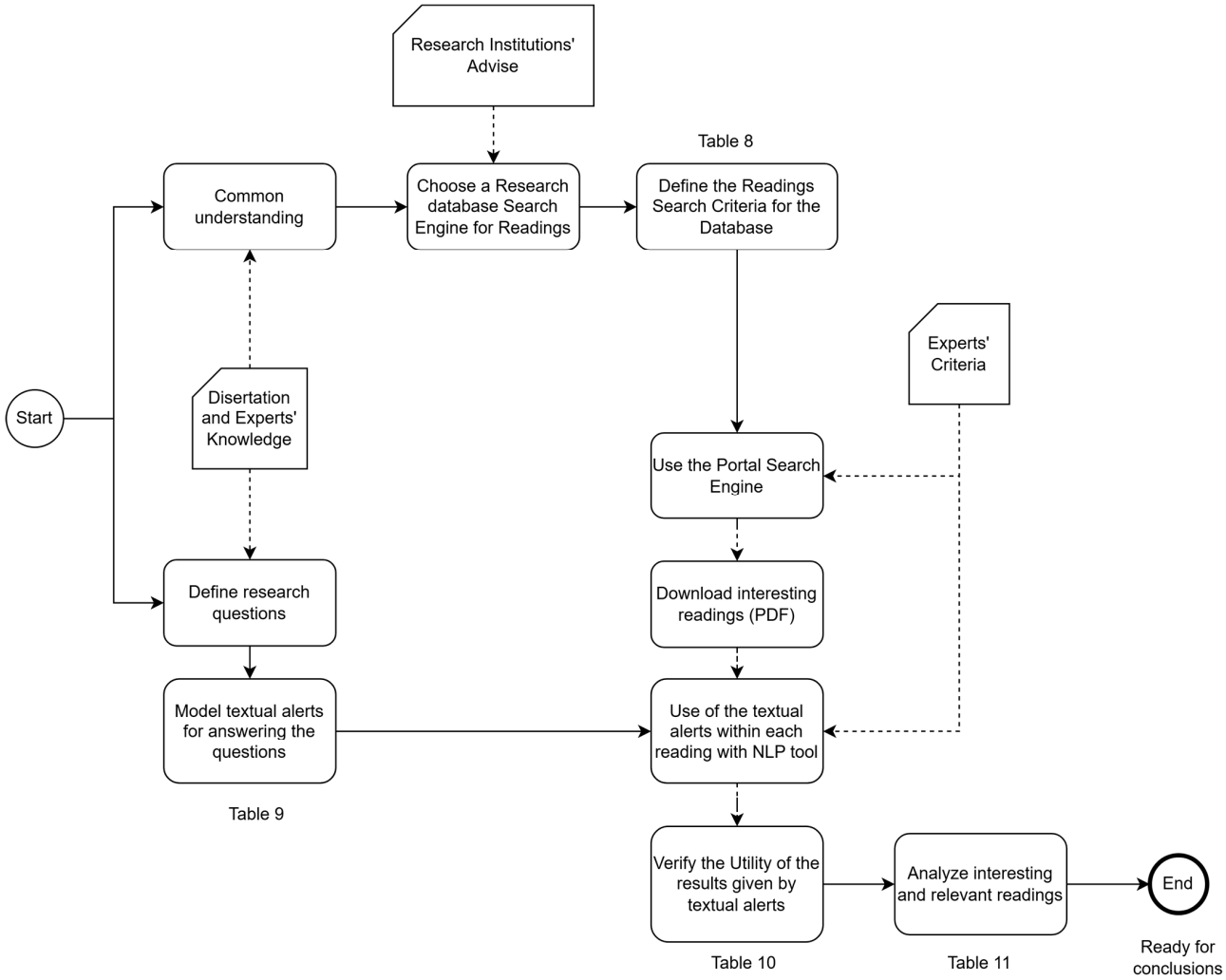



**Figure 5.** Research materials and methods summary. Table captions are for tables in this text.

**Table 9.** Textual alert composition with extended clusters.

| Question | Filter Cluster | Context Cluster | [Pattern 1] | [Pattern 2] |
|---|---|---|---|---|
| (Q3) Is MBSE-NLP-AI being used in open innovation environments? | Keywords | Cluster | <Filter>. . .<Cluster> | The reverse of pattern 1 |
| (Q4) Is MBSE-NLP-AI being used for risk management? | Keywords | Cluster | <Filter>. . .<Cluster> | The reverse of pattern 1 |
| (Q5) Is MBSE-NLP-AI being used for governance? | Keywords | Cluster | <Filter>. . .<Cluster> | The reverse of pattern 1 |

**Table 10.** Question and research utility validation (R = relevant; I = interesting but not necessarily relevant; IR = irrelevant).

| Id | Bibliography Index (DOI) and Title | Verification | | |
|---|---|---|---|---|
| | | Q3 | Q4 | Q5 |
| 1 | https://doi.org/10.1016/j.compeleceng.2024.109409 A systematic review of trustworthy artificial intelligence applications in natural disasters | IR | R | I |
| 2 | https://doi.org/10.1016/j.compind.2021.103447 Data science for engineering design: State of the art and future directions | I | I | R |

**Table 10.** *Cont.*

| Id | Bibliography Index (DOI) and Title | Verification | | |
|---|---|---|---|---|
| | | Q3 | Q4 | Q5 |
| 3 | https://doi.org/10.1016/j.compind.2023.103996 Automatic definition of engineer archetypes: A text mining approach | R | IR | IR |
| 4 | https://doi.org/10.1016/j.compind.2025.104251 Automated construction contract analysis for risk and responsibility assessment using natural language processing and machine learning | I | R | IR |
| 5 | https://doi.org/10.1016/j.datak.2023.102246 The power and potentials of Flexible Query Answering Systems: A critical and comprehensive analysis | IR | IR | I |
| 6 | https://doi.org/10.1016/j.jmsy.2024.10.011 Interoperable information modelling leveraging asset administration shell and large language model for quality control toward zero defect manufacturing | IR | IR | I |
| 7 | https://doi.org/10.1016/j.autcon.2022.104391 IM-based construction safety risk library | I | R | IR |
| 8 | https://doi.org/10.1016/j.autcon.2023.104951 Generating risk response measures for subway construction by fusion of knowledge and deep learning | IR | R | IR |
| 9 | https://doi.org/10.1016/j.cja.2021.08.016 Large-scale real-world radio signal recognition with deep learning | IR | I | IR |
| 10 | https://doi.org/10.1016/j.jnca.2021.103210 A selective ensemble model for cognitive cybersecurity analysis | I | IR | IR |
| 11 | https://doi.org/10.1016/j.aej.2025.01.028 Applying multi-criteria decision-making to text analysis for optimizing engineering knowledge management | I | I | IR |
| 12 | https://doi.org/10.1016/j.aei.2024.102653 A platform-based Natural Language processing-driven strategy for digitalising regulatory compliance processes for the built environment | R | IR | IR |
| 13 | https://doi.org/10.1016/j.aei.2024.102735 Intermediate representations to improve the semantic parsing of building regulations | I | IR | IR |
| 14 | https://doi.org/10.1016/j.inffus.2024.102795 Has multimodal learning delivered universal intelligence in healthcare? A comprehensive survey | IR | I | IR |
| 15 | https://doi.org/10.1016/j.procir.2023.03.125 Requirements extraction from engineering standards systematic evaluation of extraction techniques | I | IR | IR |
| 16 | https://doi.org/10.1016/j.mfglet.2024.09.143 High-resolution time-series classification in smart manufacturing systems | IR | I | IR |
| 17 | https://doi.org/10.1016/j.cscm.2024.e04014 Frost durability of cementitious materials: What's next? | I | I | IR |
| 18 | https://doi.org/10.1016/j.jestch.2024.101675 Innovative agricultural ontology construction using NLP methodologies and graph neural network | IR | I | IR |
| 19 | https://doi.org/10.1016/j.teler.2024.100173 Advancements in natural language processing: Implications, challenges, and future directions | IR | I | IR |
| 20 | https://doi.org/10.32604/cmc.2022.027223 An Efficient Stacked-LSTM Based User Clustering for 5G NOMA Systems | I | IR | IR |
| 21 | https://doi.org/10.32604/cmc.2024.041949 Software Vulnerability Mining and Analysis Based on Deep Learning | IR | I | IR |

**Table 11.** Improvements for the model from relevant readings (with literal text).

| Id | Reading Title | Evidence for MBSE-NLP-AI | KET | Potential Improvement for the SAVE Model |
|---|---|---|---|---|
| 1 | [76] *A systematic review of trustworthy artificial intelligence applications in natural disasters,* | *Researchers have highlighted the importance of optimizing EWSs using AI and XAI. AI-driven decision-making with human expertise can lead to better decision-making processes.* | AI | Governance |
| 2 | [77] *Data science for engineering design: State of the art and future directions,* | *Design tools are producing increasing amounts of data that can be exploited to support all the different phases of ED, including its most creative aspects that are traditionally not supported by classical optimization-based methodologies* | Models | Systems Engineering |
| 3 | [78] *Automatic definition of engineer archetypes: A text mining approach,* | *Engineering archetypes have been defined here as clusters of competences* | AI | Systems Engineering |
| 4 | [79] *Automated construction contract analysis for risk and responsibility assessment using natural language processing and machine learning,* | *Despite the vital role of construction contracts in determining the risks, rights, and obligations assigned to contracting parties, an exhaustive analysis of lengthy contract documents during tight bidding schedules remains a persistent challenge.* | NLP | Governance |
| 7 | [80] *BIM-based construction safety risk library,* | *A commercial digital tool (SafetiBase in 3D Repo) that is being actively employed by the industry on BIM-enabled projects, the creation of a foundational library of health and safety knowledge that is accessible and open to further enhancement is a further contribution of the research.* | Models | Building |
| 8 | [81] *Generating risk response measures for subway construction by fusion of knowledge and deep learning,* | *To adapt to the complex and changing construction environment and achieve scientific prevention and pre-control of accidents, the intelligence level of the decision-making practice relevant to construction risk management . . . should be improved. This study proposed a method to generate risk response measures.* | AI | Building |
| 11 | [82] *Applying multi-criteria decision-making to text analysis for optimizing engineering knowledge management,* | *Future direction: Use AI-driven predictive models to forecast the long-term impacts of alternative decisions, enabling robust multi-period analysis.* | AI | Governance |
| 12 | [83] *A platform-based Natural Language processing-driven strategy for digitalising regulatory compliance processes for the built environment,* | *A platform-based approach for digitalising regulatory requirements processing spanning authoring, designing and compliance checking was presented. The proposed approach comprises of several tools integrated together as required with the processor of corpus of regulatory documents underlying the whole platform accessed by all the various tools.* | NLP | Systems Engineering |

**Table 11.** *Cont.*

| Id | Reading Title | Evidence for MBSE-NLP-AI | KET | Potential Improvement for the SAVE Model |
|---|---|---|---|---|
| 17 | [84] *Frost durability of cementitious materials: What's next?,* | *This paper presented the analysis of trends in research on the FT durability of concrete. The key innovation of this research lies in the systematic application of semi-automatic NLP* | NLP | Building |
| 19 | [85] *Advancements in natural language processing: Implications, challenges, and future directions,* | *PRISMA guarantees a comprehensive and impartial examination of the literature, while NLP identifies the most significant terms, offering equitable and comprehensive summaries*. | NLP | Governance |

## 3. Results Summary and Discussion

Using the ScienceDirect portal, 92 works were found. After eliminating inaccessible or out-of-scope readings, 21 works were selected for textual processing, with alerts and further analysis by the authors. The results are shown in Table 10. The data were stored in Excel™ tables. Notice that 90% of the reading represented an interest in more than one of the questions or relevant results to consider MBSE-NLP-AI, as shown in Table 11.

As can be seen, there are interesting and relevant readings for each question, but, statistically, risk management and innovation (37% and 26%, respectively) are more significative than governance (10%). Governance could be missing in engineering and research.

At this point, it is possible to say that recent research works combine AI, NLP, and models, automatizing several supervisory tasks, thus potentially improving governance, engineering (as in buildings), and systems engineering. There are other large research databases to explore before labeling these results as definitive but none of the found works covered the MBSE-NLP-AI combination, which motivated this research. Regarding the results and despite the statistics, they might not be representative unless more research databases are used, AI is used for governance, NLP is cross-cutting, and models are used for engineering in general. Regarding governance, none of the references specifically focused on program supervision.

## 4. Conclusions and Next Steps

The SAVE model presented in this work is a plausible framework for approaching a transformative impact on an agri-regions or rural areas from an engineering perspective. This approach is notably distinct from that of the social sciences, yet it remains complementary. The model can be adapted to various rural regions, regardless of the paradigms or disciplines involved, as long as they share the common goal of achieving smart governance in the era of information technologies. This also facilitates collaboration with other countries for diverse purposes while addressing similar needs to promote the smart agri-region value engineering concept, ultimately aiding in the escape from the "middle-income trap" through the adoption of foreign technologies. This initiative aims to establish a knowledge base that facilitates international technological cooperation governance while enhancing collaboration within the building sector, which is recognized for its exemplary practices. To achieve this, program governance must focus on various metrics that are more cost-effective than detailed engineering approaches.

The primary conclusion of this work is that there exists a potential deficiency in R&D projects focused on the advanced application of drones for construction or solar energy

within a circular economy framework. This sets the foundation for replication, as typically funded by the European Commission. However, there is sufficient knowledge available to begin reusing existing resources, thereby avoiding the need to reinvent the wheel.

As in this work, the academia can play an important role by improving interdisciplinary but independent research.

The second conclusion of this work suggests that a region or country is likely to acquire specific tools for engineering reporting at program governance levels (MBSE-NLP-AI) to promote the smart agri-region value engineering concept. If necessary, this could involve activating the public procurement of innovation, as outlined in guidelines [86]. However, the lack of emphasis on governance within the engineering research community may pose a significant obstacle. Further steps in this research necessitate a regional intercomparison of AI capabilities to assess whether key concepts, such as smart agri-region value engineering, can be effectively implemented in real-world scenarios. This includes the establishment of solar energy plants for a circular economy and the inspection of rural building rehabilitation, both of which are interconnected systems reliant on communications and services. These concepts are highly replicable across various Mediterranean regions. Another way to progress is to participate in an international R&D and innovation project but, to do so, it would be necessary to reassess the demographic similarity assessment to the participant countries and regions, and to deeply assess the digitalization policies and economic structures of such regions. For example, Extremadura offers digital twins and R&D grants accessible to SMEs. The latter facilitates the engineering of SAVE agri-regional systems and others, under European Research Area (ERA) policies [2]. Digital twins, however, require reverse engineering and development—essentially systems engineering—which face specific challenges such as interoperability due to neutral technology regulations. This highlights the need for research into regulatory gaps that affect the use of systems engineering practices for governing System of Systems (SoS). While digital twins do not pose physical risks, they can produce relevant social, environmental, and technical KPIs during development, much like physical systems. In this context, the region also benefits from innovation infrastructures [87].

The engineering work products could be further processed by MBSE-NLP-AI tools to generate a smart program governance demonstration. Additionally, they could be utilized in a pilot program in Extremadura, which aims to verify the contextual assumption that engineering professionals can prioritize rural areas. This would involve incorporating a social assessment within the pilot, where mobility and aeronautics could significantly contribute by expanding research into the application of these disciplines.

**Author Contributions:** Conceptualization, R.P.; methodology, R.P.; investigation, R.P., J.P.C., P.G.R. and A.L.; writing—original draft preparation, R.P., A.L., J.P.C. and P.G.R. writing—review and editing, R.P., A.L., J.P.C. and P.G.R. All authors have read and agreed to the published version of the manuscript.

**Funding:** This research received no external funding.

**Acknowledgments:** The authors thank the REUSE company for assisting in using SES ENGINEERING Studio's RISK&ALERTS and KM-KNOWLEDGE manager capabilities. Also, thanks go to Anabel Fraga from UC3M University who showed us the importance of systems engineering for governance, and the Spanish Platform on Safety and Security (PESI) for introducing mobility and safety paradigms.

**Conflicts of Interest:** Author Raúl Pastor was employed by the company Seam Start-Up,POLYSOL GESTION. The remaining authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

## References


1. European Commission. The European Green Deal—Striving to Be the First Climate-Neutral Continent. 2024. Available online: https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal_en (accessed on 21 January 2024).
2. European Commission. European Research Area (ERA). 2024. Available online: https://research-and-innovation.ec.europa.eu/strategy/strategy-2020-2024/our-digital-future/european-research-area_en (accessed on 17 September 2024).
3. *ISO/IEC 25000:2014*; Systems and software engineering—Systems and software Quality Requirements and Evaluation (SQuaRE)—Guide to SQuaRE. ISO: Geneva, Switzerland, 2014. Available online: https://www.iso.org/obp/ui/#iso:std:iso-iec:25000:ed-2:v1:en (accessed on 17 April 2025).
4. ASTM. Standard Practice for Performing Value Engineering (VE)/Value Analysis (VA) of Projects, Products and Processes. 2020. Available online: https://store.astm.org/e1699-14r20.html (accessed on 17 April 2025).
5. ICMA. 2021. Available online: https://www.icmagroup.org/assets/documents/Sustainable-finance/2021-updates/GBP-IRWG-Suggested-Impact-Reporting-Metrics-for-Circular-Economy-andor-Eco-Efficient-Projects-June-2021-100621.pdf (accessed on 17 April 2025).
6. European Commission. *Proposal for a Directive on Corporate Sustainability Due Diligence and Annex*; in D. J. EU (Directorate-General for Justice and Consumers); European Commission: Brussels, Belgium, 2022.
7. Ortega, J.; Vasconcelos, G.; Rodrigues, H.; Correia, M. A vulnerability index formulation for the seismic vulnerability assessment of vernacular architecture. *Eng. Struct.* **2019**, *197*, 109381. [CrossRef]
8. Bodach, S.; Lang, W.; Hamhaber, J. Climate responsive building design strategies of vernacular architecture in Nepal. *Energy Build.* **2014**, *81*, 227–242. [CrossRef]
9. Li, N.; Zhang, F.; Geng, W.; Li, Z. Research on performance improvement design strategies for urban historic districts and suburban traditional villages in multiple scopes. *J. Build. Eng.* **2023**, *72*, 106342. [CrossRef]
10. Chen, W.; Yang, Z.; Yan, H.; Zhao, Y. How to reduce construction risks in rural areas: An evolutionary game analysis. *Eng. Constr. Archit. Manag.* **2024**. *ahead of print*. [CrossRef]
11. Tsai, S.-C.; Zhang, X.-F.; Chang, Y.-T. Toward Nearly Zero-Waste Architecture Innovation: Innovation, Application, and Practice of Construction Methods Using Natural Materials. *Buildings* **2024**, *14*, 1584. [CrossRef]
12. Daumal, F.; Monzón, M.; López-Mesa, B. La necesidad de conciliar la normativa de habitabilidad con la rehabilitación acústica de la vivienda mínima. *Inf. Construcción* **2018**, *70*, e241. [CrossRef]
13. Bournas, D.A. Concurrent seismic and energy retrofitting of RC and masonry building envelopes using inorganic textile-based composites combined with insulation materials: A new concept. *Compos. Part B Eng.* **2018**, *148*, 166–179. [CrossRef]
14. Rocco, A.; Vicente, R.; Rodrigues, H.; Ferreira, V. Adobe Blocks Reinforced with Vegetal Fibers: Mechanical and Thermal Characterization. *Buildings* **2024**, *14*, 2582. [CrossRef]
15. Kabore, A.; Laghdir, A.; Ouellet-Plamondon, C. Natural thermal and hygrothermal regulation with heavy cob for low carbon construction. *Constr. Build. Mater.* **2024**, *451*, 138832. [CrossRef]
16. Ullah, H.; Zhang, H.; Ye, H.; Ali, I.; Cong, M. Research on Low-Carbon Design and Energy Efficiency by Harnessing Indigenous Resources through BIM-Ecotet Analysis in Hot Climates. *Sustainability* **2024**, *16*, 6057. [CrossRef]
17. González-Redondo, E. De la construcción entramada a la introducción de estructuras metálicas en Madrid. *Inf. Construcción* **2014**, *66*, e025. [CrossRef]
18. Berdahl, P.; Akbari, H.; Levinson, R.; Miller, W. Weathering of roofing materials—An overview. *Constr. Build. Mater.* **2008**, *22*, 423–433. [CrossRef]
19. Fan, J.; Wang, D.; Liu, P.; Xu, J. Research on the Prediction of Sustainable Safety Production in Building Construction on Text Data. *Sustainability* **2024**, *16*, 5081. [CrossRef]
20. Mol, A.; Cabaleiro, M.; Sousa, H.; Branco, J. HBIM for storing life-cycle data regarding decay and damage in existing timber structures. *Autom. Constr.* **2020**, *117*, 103262. [CrossRef]
21. Bouzas, O.; Cabaleiro, M.; Conde, B.; Cruz, Y.; Riveiro, B. Structural health control of historical steel structures using HBIM. *Autom. Constr.* **2022**, *140*, 104308. [CrossRef]
22. Cortés, J.; Cortés, A.; Prieto-Muriel, P. BIM-integrated management of occupational hazards in building construction and maintenance. *Autom. Constr.* **2020**, *113*, 103115. [CrossRef]
23. Bolshakov, N.; Rakova, X.; Celani, A.; Badenko, V. Operation Principles of the Industrial Facility Infrastructures Using Building Information Modeling (BIM) Technology in Conjunction with Model-Based Engineering (MBSE). *Appl. Sci.* **2023**, *13*, 11804. [CrossRef]
24. Doukari, O.; Wakefield, J.; Martinez, P.; Kassem, M. An ontology-based tool for safety management in building renovation projects. *J. Build. Eng.* **2024**, *84*, 108609. [CrossRef]
25. Ding, L.; Zhong, B.; Wu, S.; Luo, H. Construction risk knowledge management in BIM using ontology and semantic web technology. *Saf. Sci.* **2016**, *87*, 202–213. [CrossRef]
26. Collinge, W.; Osorio-Sandoval, C. Deploying a Building Information Modelling (BIM)-Based Construction Safety Risk Library for Industry. *Lessons Learn. Future. Dir.* **2024**, *14*, 500.

27. Locatelli, M.; Seghezzi, E.; Pellegrini, L.; Tagliabue, L.; Di Giuda, G. Exploring Natural Language Processing in Construction and Integration with Building Information Modeling: A Scientometric Analysis. *Buildings* **2021**, *11*, 583. [CrossRef]
28. Wang, H.; Meng, X.; Zhu, X. Improving knowledge capture and retrieval in the BIM environment: Combining case-based reasoning and natural language processing. *Autom. Constr.* **2022**, *139*, 104317. [CrossRef]
29. Shen, Q.; Wu, S.; Deng, Y.; Deng, H.; Cheng, J. BIM-Based Dynamic Construction Safety Rule Checking Using Ontology and Natural Language Processing. *Buildings* **2022**, *12*, 564. [CrossRef]
30. Kumar, B.; Raj, A.; Szepesi, G.; Szamosi, Z. A conspectus review on solar drying of wood: Regional and technical contrivances. *J. Therm. Anal. Calorim.* **2023**, *148*, 9237–9261. [CrossRef]
31. Lamrani, B.; Bekkioui, N.; Simo-Tagne, M.; Ndukwu, M. Recent progress in solar wood drying: An updated review. *Dry. Technol.* **2022**, *41*, 605–627. [CrossRef]
32. Gil, L. Solar energy and cork: A binomial of the future? *Sci. Technol. Mater.* **2018**, *40*, 80–86. [CrossRef]
33. ObCP. La implementación de la metodología BIM en la Contratación Pública. 2024. Available online: https://www.obcp.es/opiniones/la-implementacion-de-la-metodologia-bim-en-la-contratacion-publica (accessed on 23 February 2025).
34. Madachy, R.; Snoderly, J.; Roedler, G. Configuration Management. SEBoK. 2024. Available online: https://sebokwiki.org/wiki/Configuration_Management (accessed on 23 February 2025).
35. IAMM. SSG 14: Configuration Management. IAMM. 2019. Available online: https://theiam.org/knowledge-library/ssg-14-configuration-management/ (accessed on 23 February 2025).
36. ISO. Systems and Software Engineering—System Life Cycle Process. 2023. Available online: https://www.iso.org/standard/81702.html (accessed on 23 February 2025).
37. *ISO 55000:2014*; Asset Management—Overview, Principles and Terminology. ISO: Geneva, Switzerland, 2014. Available online: https://www.iso.org/obp/ui#iso:std:iso:55000:ed-1:v2:en (accessed on 23 February 2025).
38. INCOSE. *Systems Engineering Handbook*; INCOSE: San Diego, CA, USA, 2015.
39. INCOSE. Power & Energy Systems Working Group. Available online: https://www.incose.org/communities/working-groups-initiatives/power-energy-systems (accessed on 23 February 2025).
40. Snoderly, J.; Faisandier, A.; Jackson, S. System Integration. 2025. Available online: https://sebokwiki.org/wiki/System_Integration (accessed on 23 February 2025).
41. IBM. 2023. Available online: https://www.ibm.com/think/topics/model-based-systems-engineering (accessed on 23 February 2025).
42. Henshaw, M.; Dahmann, J.; Lawson, B. Guide to the Systems Engineering Body of Knowledge (SEBoK). 2024. Available online: https://sebokwiki.org/wiki/Systems_of_Systems_(SoS) (accessed on 6 June 2024).
43. SCI. Smart Cities Initiative. 2022. Available online: https://www.incose.org/2021-redesign/working-groups-v1/smart-cities (accessed on 29 October 2022).
44. Sancho, J.; Caro, A.; Rodríguez, P. A Preventive Secure Software Development Model for a Software Factory: A Case Study. *Comput. Sci. Inf. Syst.* **2020**, *8*, 77653–77665.
45. Barrena, M.; Caro, A.; Durán, M.; Rodríguez, P.; Arias-Nicolás, J.; Alonso, T. Qatris iManager: A general purpose CBIR system. *Mach. Vis. Appl.* **2015**, *26*, 423–442. [CrossRef]
46. Molano, R.; Sancho, J.; Ávila, M.; Rodríguez, P.; Caro, A. Obtaining the user-defined polygons inside a closed contour with hole. The Visual Computer. *Comput. Sci. Softw. Eng.* **2023**, *34*, 6369–6387.
47. Ferrán, A.; Bernabé, S.; Rodríguez, P.; Plaza, A. A Web-Based System for Classification of Remote Sensing Data. *Imaging Sci. Photograhic Technol.* **2013**, *6*, 1943–1948. [CrossRef]
48. Sánchez, M.; Cuartero, A.; Barrena, M.; Plaza, A. A New Method for Positional Accuracy Analysis in Georeferenced Satellite Images without Independent Ground Control Points. *Remote Sens.* **2020**, *12*, 4132. [CrossRef]
49. Cuartero, A.; Paoletti, M.; Rodríguez, P.; Haut, M. QcircularStats: A QGIS-plugin for evaluation bidomensional data by circular statistics. *Comput. Sci. Inf. Syst.* **2023**, *11*, 47552–47562. [CrossRef]
50. Zhu, H.; Huang, M.; Zhang, Q.-B. TunGPR: Enhancing data-driven maintenance for tunnel linings through synthetic datasets, deep learning and BIM. *Tunn. Undergr. Space Technol.* **2024**, *145*, 105568. [CrossRef]
51. Wettewa, S.; Hou, L.; Zhang, G. Graph Neural Networks for building and civil infrastructure operation and maintenance enhancement. *Adv. Eng. Inform.* **2024**, *62*, 102868. [CrossRef]
52. Sammartano, G.; Avena, M.; Fillia, E.; Spanò, A. Integrated HBIM-GIS Models for Multi-Scale Seismic Vulnerability Assessment of Historical Buildings. *Remote Sens.* **2023**, *15*, 833. [CrossRef]
53. Froner, Y.A.; de Barros Gonçalves, W.; Souza, L.; Costa, A.G.; Rosado, A.; Cuperschmid, A.R.M.; Walter, G.d.O.; Miranda, A.C.N.; Michelin, G.; Hardy, T. Data Collection for Cultural Heritage Risk Management: The Damage Map through Heritage Building Information Modeling (HBIM) Project Applied to the Façade of St Francis of Assisi, Ouro Preto, Brazil. *Stud. Conserv.* **2024**, *69*, 98–107. [CrossRef]

54. Zhang, J.; Chan, C.; Kwok, H.H.; Cheng, J.C. Multi-indicator adaptive HVAC control system for low-energy indoor air quality management of heritage building preservation. *Build. Environ.* **2023**, *246*, 110910. [CrossRef]
55. Mellado, F.; Wong, P.F.; Amano, K.; Johnson, C. Digitisation of existing buildings to support building assessment schemes: Viability of automated sustainability-led design scan-to-BIM process. *Archit. Eng. Des. Manag.* **2019**, *16*, 84–99. [CrossRef]
56. Ursini, A.; Grazzini, A.; Matrone, F.; Zerbinatti, M. From scan-to-BIM to a structural finite elements model of built heritage for dynamic simulation. *Autom. Constr.* **2022**, *142*, 104518. [CrossRef]
57. AEMET. Atlas de Radiación Solar en España utilizando datos del SAF de Clima EUMETSAT. 2012. Available online: https://www.aemet.es/documentos/es/serviciosclimaticos/datosclimatologicos/atlas_radiacion_solar/atlas_de_radiacion_24042012.pdf (accessed on 26 February 2025).
58. Junta de Extremadura, Diputación de Badajoz y Diputación de Cáceres. Orden selección de estrategias DLP 2014–2020. 2016. Available online: https://redex.org/ficheros/archivos/2017_05/la-siberia-anexo-3.pdf (accessed on 26 February 2025).
59. Lecuona-Neumann, A.; Famiglietti, A. Direct gas heating in linear concentrating solar collectors for power and industrial process heat production: Application and challenges. *Wiley Energy Environ.* **2023**, *12*, e471. [CrossRef]
60. Castro, A.B.; Alvarado, R.G. BIM-Integration of solar thermal systems in early housing design. *J. Constr.* **2017**, *16*, 323–338.
61. Pelay, U.; Luo, L.; Fan, Y.; Stitou, D. Dynamic modeling and simulation of a concentrating solar power plant integrated with a thermochemical energy storage system. *J. Energy Storage* **2020**, *28*, 101164. [CrossRef]
62. Sun, X.; Wang, S.; Zhang, X.; Wandelt, S. LAERACE: Taking the policy fast-track towards low-altitude economy. *J. Air Transp. Res. Soc.* **2025**, *4*, 100058. [CrossRef]
63. Qin, Y.; Kishk, M.A.; Alouini, M.-S. Performance Analysis of Charging Infrastructure Sharing in UAV and EV-Involved Networks. *IEEE Trans. Veh. Technol.* **2023**, *72*, 3973–3988. [CrossRef]
64. EC. Categorisation System for the Circular Economy A Sector-Agnostic Approach for Activities Contributing to the Circular Economy. 2020. Available online: https://circulareconomy.europa.eu/platform/sites/default/files/categorisation_system_for_the_ce.pdf (accessed on 24 February 2025).
65. Nakamura, G. Harvesting forest biomass reduces wildfire fuel. *Calif. Agric.* **1996**, *50*, 13–16. [CrossRef]
66. EC. Contribution of Forest Biomass Generated in the Prevention of Forest Fires in the EU Energy Strategy. BIOENERGY & FIRE PREV. on LIFE Public Database. 2013. Available online: https://webgate.ec.europa.eu/life/publicWebsite/project/LIFE09-ENV-ES-000450/contribution-of-forest-biomass-generated-in-the-prevention-of-forest-fires-in-the-eu-energy-strategy (accessed on 24 February 2025).
67. Shahidul, I.; Byzed, H. An overview of the effects of water and moisture absorption on the performance of hemp fiber and its composites. *SPE Polym.* **2025**, *6*, e10167.
68. EC. EU Taxonomy for Sustainable Activities. Finance. 2020. Available online: https://finance.ec.europa.eu/sustainable-finance/tools-and-standards/eu-taxonomy-sustainable-activities_en (accessed on 4 December 2022).
69. CIMDATA. Systems Engineering Rigor Needs an Interoperability Framework. 2022. Available online: https://www.cimdata.com/en/resources/complimentary-reports-research/commentaries/item/20310-systems-engineering-rigor-needs-an-interoperability-framework-the-reuse-company-s-ses-engineering-studio-is-such-a-framework-commentary (accessed on 21 April 2024).
70. WB. World Development Report 2024: Main Messages. 2024. Available online: https://www.worldbank.org/en/publication/wdr2024/brief/world-development-report-2024-main-messages (accessed on 25 February 2024).
71. Pastor, R.; Fraga, A.; López-Cózar, L. Interoperable, Smart, and Sustainable Urban Energy Systems. *Sustainability* **2023**, *15*, 13491. [CrossRef]
72. Pastor, R.; Fraga, A.; Larrañeta, J.J. i-ISSUES—Industrial-Interoperable Safe and Secure Urban Energy Systems. *Appl. Sci.* **2024**, *14*, 3188. [CrossRef]
73. Pastor, R.; Lecuona, A.; Fraga, A. re-ISSUES—Renewable Energy-Linked Interoperable Smart and Sustainable Urban Environmental Systems. *Processes* **2024**, *121*, 1815. [CrossRef]
74. Pastor, R.; Lecuona, A.; Cortés, J.P.; Caballero, D.; Fraga, A. Rural-Interoperable System of Systems for Unified Environmental Stewardship. *Appl. Sci.* **2024**, *14*, 8245. [CrossRef]
75. Pastor, R.; Lecuona, A.; Fraga, A. Public purchase of innovation for sustainable solar urban energy systems. *Acad. Eng.* **2024**, *1*, acadeng7315. [CrossRef]
76. Albahri, A.; Khaleel, Y.L.; Habeeb, M.; Ismael, R.D.; Hameed, Q.A.; Deveci, M.; Homod, R.Z.; Albahri, O.; Alamoodi, A.; Alzubaidi, L. A systematic review of trustworthy artificial intelligence applications in natural disasters. *Comput. Electr. Eng.* **2024**, *118*, 109409. [CrossRef]
77. Chiarello, F.; Belingheri, P.; Fan, G. Data science for engineering design: State of the art and future directions. *Comput. Ind.* **2021**, *129*, 103447. [CrossRef]
78. Lupi, F.; Mabkhot, M.; Boffa, E.; Ferreira, P.; Antonelli, D.; Maffei, A.; Lohse, N.; Lanzetta, M. Automatic definition of engineer archetypes: A text mining approach. *Comput. Ind.* **2023**, *152*, 103996. [CrossRef]

79. Dikmen, I.; Eken, G.; Huseyin, E.; Talat Birgonul, M. Automated construction contract analysis for risk and responsibility assessment using natural language processing and machine learning. *Comput. Ind.* **2025**, *166*, 104251. [CrossRef]
80. William, H.; Farghaly, K.; Mojgan Hadi, M.; Manu, P.; Cheung, C.M.; Osorio-Sandoval, C.A. BIM-based construction safety risk library. *Autom. Constr.* **2022**, *141*, 104391.
81. Zhou, H.; Huang, W.; Zhao, X.; Tang, S. Generating risk response measures for subway construction by fusion of knowledge and deep learning. *Autom. Constr.* **2023**, *152*, 104951. [CrossRef]
82. Zhang, D. Applying multi-criteria decision-making to text analysis for optimizing engineering knowledge management. *Alex. Eng. J.* **2025**, *117*, 648–661. [CrossRef]
83. Kruiper, R.; Bimal, B.; Watson, R.; Sadeghineko, F.; Gray, A.; Konstas, I. A platform-based Natural Language processing-driven strategy for digitalising regulatory compliance processes for the built environment. *Adv. Eng. Inform.* **2024**, *62*, 102653. [CrossRef]
84. Rajczakowska, M.; Novakova, I.; Adediran, A.; Perumal, P.; Wallevik, Ó.H.; Cwirzen, A. Frost durability of cementitious materials: What's next? *Case Stud. Constr. Mater.* **2024**, *21*, e04014. [CrossRef]
85. Supriyono; Wibawa, A.P.; Suyono; Fachrul, K. Advancements in natural language processing: Implications, challenges, and future directions. *Telemat. Inform. Rep.* **2024**, *16*, 100173. [CrossRef]
86. European Commission Guidance on Public Procurement of Innovation. 2017. Available online: https://ec.europa.eu/docsroom/documents/25724/attachments/1/translations/en/renditions/native (accessed on 16 March 2024).
87. FUNDECYT-PTEX. Incubadora de Realidades Inmersivas de Almendralejo. 2024. Available online: https://iriavr.es/ (accessed on 30 May 2025).


**Disclaimer/Publisher's Note:** The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.