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CONTENTS

How Do We Optimize Risk in Enterprise Architecture when Deploying Emerging Technologies?

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Abstract. Emerging Technologies which merge cyber-physical systems continue to transform businesses and digital agility in transformative ways. Importantly, most investigations around focus on either cyber risk or the risk around physical systems but it does not encompass both. However, the immediate challenge is new opportunities occurring with emerging technologies. Examples include automobiles, the Internet of Things (IoT), medical devices, and building controls. In this study we will focus identifying risk as an optimization not a minimization problem and how to develop a practical approach for executives and boards to use in the oversight of cyber physical systems. Based on interviews with executive leadership teams and boards of directors we explored the over-arching research question: How can we apply a risk-based approach to cyber-physical security and what questions should business leaders be asking? The research methodology used a survey instrument and multiple qualitative methods involving business leaders from 60 companies and 80 business leaders from September 2018 – September 2019. Based on this analysis, we developed an extended framework for executives, as well as questions and process for boards to consider as part of their oversight. The Extended Risk-Based Approach equips boards and executives as they begin to develop their thinking around enterprise cyber physical risk.

Keywords: Emerging Technologies, Cyber Security, Information Security, Cyber Physical Risk, Internet of Things (IoT)

1. Introduction

Many corporate executives and boards are not familiar with how to organize, understand and communicate cyber-physical risk priorities in ways that help the organization make the best possible decisions around how to address this risk. To compound this problem corporate culture might be in place that decreases any motivation for leaders to report bad news. Failure to address risk creates liability for board and executives due to negligence. In addition, the area of greatest concern for enterprise risk is in the information security area [1]. Furthermore, this area has expanded in scope increasing the need for tools to address cyber-physical risk. The goal of this research is to first understand the executive perspective on the current state of emerging technology deployment and risk and then to ascertain from executives and business leaders what would be most useful in terms of assisting decision-making in this area. The critical research question is: How can we apply a risk-based approach to cyber-physical security and what questions should business leaders to be asking?

The growth and expansion of IoT and emerging technologies across all industry sectors means this is a critical time for understanding and addressing cyber-physical risk. A broad range of new devices are now enabled because of the increasing

capabilities in networking, computing, sensing and control systems. Unfortunately, the volume and expansion of this attack surface does not coincide with current capabilities or approaches for dealing with it. Companies driven by functional requirement and swiftly changing market demands must move quickly to create new value and succeed. Standards are just emerging, designs are changing rapidly, and devices with lifespans measured in decades are being deployed. The means that current design choices will impact the next several decades of cyber-physical security across all sectors including: transportation, aviation, health care, building controls, emergency response, communications, and most other sectors.

We now drive cars that are connected to the internet, receive automated electronic updates, automatically brake to avoid collisions, and even have some self-driving features. We depend on medical devices that are highly interconnected across old and new enterprise architecture that can monitor conditions real-time and adapt to changes. Our homes have well-integrated smart devices that impact home-security, electricity usage, and connect all of our entertainment systems. When security is overlooked, the risk includes unintentional faults or malicious attacks changing how cars brake, how medical devices work and how smart devices respond to events. Cyber-physical security becomes significantly more complicated as billions of devices with security vulnerabilities are added. Addressing cyber physical by bolting solutions onto newly deployed systems is neither viable nor sustainable over the long-term. Researchers have suggested that security issues must be analyzed, understood and addressed in the early stages of design and deployment for all emerging technologies [2,3]. Importantly, executives and the board are required to provide oversight, yet are not well-equipped to do so. A cyber-physical risk management approach should encompass risk and reward within a holistic framework. Typically, this would be done at least on an annual basis. Over time, risk could then be optimized to increase potential for profit and successful outcomes while reducing exposure. As risk is optimized opportunities increase [4].

We will build on previous work developing a risk-based approach for securing our current complex enterprise architecture and agile data center environments which no longer have a perimeter [5,6]. The research methodology involved interviews with 60 executives from 80 companies from Sept 2018-2019. Using this analysis, we developed an information security framework for executives in this new environment that builds on previous work. This framework is called the Extended Risk-Based Approach and provides businesses with an approach for securing an enterprise as emerging technologies are deployed. This research offers insight by methodically identifying and characterizing the main problems companies are facing in this context as well as providing a practical framework and tools for making better security decisions with emerging technologies. This paper proposes a different model for addressing security with the growth of agile data architecture and emerging technologies. It suggests focusing on project life-cycle, the deployment process, and constantly asking questions to identify risk as part of the project management organization.

In the IoT and cloud-security literature research primarily focusses on requirements and solutions for requirements [7] or on the broader issues of AI deployment and ethics [8,9]. Non-repudiation is widely discussed and cited [10,11,12] and Security Auditing has been deeply explored [13-15]. The most researched topics were privacy, confidentiality, access and control [16,17]. In his extensive literature review of the information security scholarship over the last decade, Honer [7] validated these areas were the topics most scholars are examining. Cyber-Physical security research focused primarily on controls [18-22]. Overall, in the applied business world, there is a need for broader thinking regarding risk, particularly in deployment, given the new agile architecture more companies are using and the increasing investment in this element of enterprise architecture.

Solutions to the requirements studied in the literature included authentication and authorization protocols as well as the use of Private Key Infrastructure. VM isolation, encryption and auditing schemes and processes were also widely studied [23]. These studies often isolated specific factors and analyzed a mixture of sub-factors providing valuable insight but also presenting practical limits when it comes to scaling and organizational decision-making. In fact, current approaches, as indicated in the literature above, assumed there is a perimeter around enterprise architecture and therefore the need for dynamic scalability was not required. This research through the research questions and case methodology explores a systematic applied approach to scaling, particularly a mixed legacy, virtual and third-party eco-system including deployment of emergent systems. This research fills a much-needed gap in providing a framework for exploring and securing this dynamic environment.

The high-level security framework used for this study is referred to as the Information Security Maturity Model (Fig. 1).

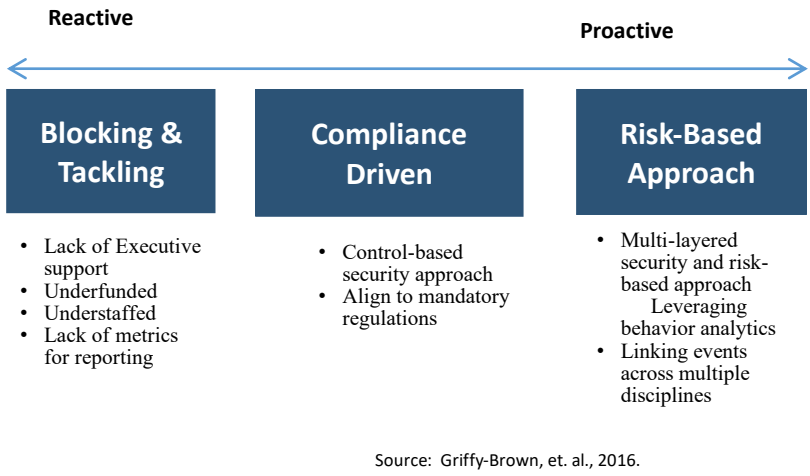

Fig. 1. The Information Security Maturity Model

This model explains that, over time, companies move from a reactive state to a proactive state with respect to cyber security. The first column, called "Blocking and Tackling" refers to a completely reactive environment. It is characterized by a lack of support, underfunding, lack of staff and lack of metrics for understanding what is happening in the IT environment with respect to cyber security. In this column, companies are typically just reacting after criminal behavior has occurred. The next column, called "Compliance Driven", refers to a corporate environment in which a control-based approach is taken but this is driven by audit and regulation rather than positioning for emerging threats. The final column called "the Risk Based Approach", refers to companies which are positioned proactively. They are using big data and behavioral analytics to understand and position themselves for potential threats. In this approach, businesses have a risk framework in place. In addition, widespread automation is in place and they are linking events across disciplines using dynamic controls, metrics and processes aligned with business.

This research first will identify where the companies examined fit within this framework particularly as they deal with emerging technologies such as IoT. After establishing this current state, we will identify what decision-making tools are required to help and then what frameworks would be useful for decision-making regarding design and accountability at the executive and board level. This study is

not an exhaustive look at the cyber-physical space and the standards required for deployment. What we hope to provide is an assessment of the current state and executive tools for decision-making given the current dynamics of deployment. It is envisioned that the development of an approach will help executives and boards as the oversee the use of more specific standards and frameworks developed by NIST, ISO, and DHS.

The structure of this paper follows this logic. The next section will explain the theory used for the underlying conversations with executives and the ongoing development of the risk-based approach. Then we will explain the methodology used to address the research question. Following this, the company responses will be examined to characterize their cyber physical risk posture according to the information security maturity model. The final section will explain the tools derived from executive discussions and processes for board oversight based on these discussions. Finally, the primary emergent themes from the analysis will be presented as overall questions for board members and executives to consider in emerging technology deployment. Based on this analysis, companies can similarly use the framework and tools presented for developing an executive approach for dealing with cyber physical risk, importantly shifting their thinking from risk minimization to risk optimization.

2. Theory

An overarching theory is required to enable scholars and practitioners to address the cyber-physical security challenge from a holistic perspective [25]. In most current studies the theory applied is largely related to creating technical controls or standards. What is missing is a broader theoretical approach beyond the technical to encompass processes of decision-making and systemic interactions, particularly as they relate to risk. In this regard, researchers have recommended three potential theoretical approaches to address extended architecture challenges, particularly security. These include: Game Theory [25], Fuzzy systems theory [25] and Graph Theory [25]. Two theories that show promise because of their dynamic but practical descriptive and modelling potential are General Systems Theory (GST) and Systems Dynamics (SD) Theory [26]. GST is based on biological systems and is used across disciplines to describe systems that exhibit unpredictable behavior occurring as a result of non-linear spatio-temporal interaction among sub-systems. Systems Dynamics models systems behavior based largely on the time-trajectory of system variables [26].

Recent studies in cyber-physical systems recommend the Systems Dynamics theory as a basis for developing standards and frameworks [19]. Work in cyber-security and IoT validated this theory as something executives could relate to in terms of decision-making [3]. The current on cyber-physical security builds on work published regarding the Risk-Based Approach [2,3] to see if this approach could extend to executive decision-making for complex emerging technologies requiring additional controls in the cyber physical space. Based on the systems dynamics theory the methodology described below was developed in which the current state is evaluated and a framework developed to continuously make design decisions to work toward a future state of increased stability.

3. Methodology

The data collection strategy used in this investigation is triangulation. It involves multiple methods for collecting historical and longitudinal data [27,28]. The data collection strategy used in this investigation first involved the collection of empirical data collected from 80 individuals from 60 firms across 12 industry verticals and

including small businesses as well as large businesses (Figure 2). Data was collected from September 2018 to September 2019. Executives and business leaders were asked for interviews as part of this study.

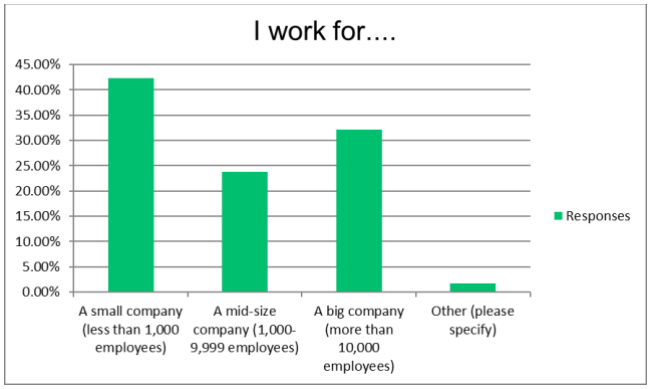

Fig. 2. Size of Businesses Surveyed

Multiple sources of data such as participant observation and company supplied data were collected along with structured and semi-structured interviews. Coding included highlighting issues that appeared more than 6 times in the interviews to develop the framework for analysis as well as to identify emerging themes and recommended solutions. The names of organizations have been kept confidential and anonymized in the reporting of the results, particularly given the sensitivity of the information security area.

In addition, the business leaders who responded were from across the organization and had high-level responsibilities within their organizations (Fig.3).

Fig. 3. Decision-making level of Respondents.

4. Results

Executives and business leaders validated this framework and even identified that their organization considered cyber risk as part of the risk management framework and not just compliance (Fig. 4). In this self-reported categorization, 80% identified themselves as incorporating cyber risk into their risk management framework which is an increase over 2016 where most indicated they were focusing on cyber risk from the perspective of compliance [5].

Fig. 4. Cyber Risk as Part of the Management Framework

Interviews indicated that one primary impediment remaining to advancing the risk-based approach was the CFO and other leadership understanding the importance of this approach for strategic development of the business. The use of audit and regulation occurred when the IT and information security groups needed funding for special projects in order to achieve business alignment. Now that compliance and regulations are increasing it will be important to understand the investment in information security from the compliance versus risk perspective given that compliance is increasing in cost. Additionally, while for most of the companies in this study, emerging technology deployment fell into a broad category of "other" IoT was identified independently. Fig. 5 shows that only about 10 percent of the companies invested in the "other" category. However, IoT is actually in the 40% range.

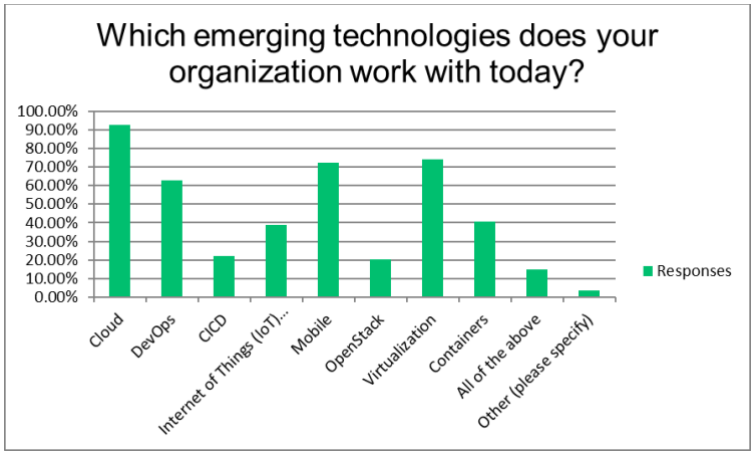

Fig. 5. The Emerging Technologies Firms are Working with Currently

What is even more significant is the elevation of cyber risk to the board level (Fig. 6). Nearly 65% of the respondents replied that the board was involved in their cyber security oversight.

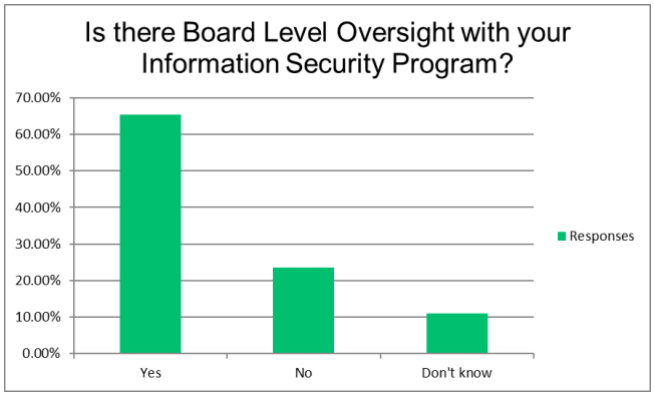

Fig. 6. Board Oversight for Cyber security

Given these changes in oversight a different security approach and framework for cyber security is required. It must be advanced beyond the IT department into enterprise operations, culture, and decision-making.

5. The Extended Risk-Based Approach to Cyber Physical

Executives and business leaders when interviewed about their cyber physical risk explained that while they were developing compliance systems for their digital systems using frameworks from NIST, ISO, CIS20, and others, they were unsure how to extend this to encompass their cyber physical needs. They universally mentioned the need for better overall processes, particularly connected to agile or waterfall project management. Connecting the decision making throughout a component lifecycle was identified as a critical need. In addition, a decision-making process connected to the Risk-Based Approach was a natural leap in business thinking. The executives and business leaders felt that an entirely new approach was not required, but instead suggested an extension of the risk-based approach. A broader rather than more specific control/compliance based approach was sought because of the rapid change in emerging technologies which were being incorporated and then exiting the architectural landscape. Therefore, an approach which would extend risk beyond project development throughout the device or software life-cycle was developed. The Extended Risk-Based Approach which resulted is demonstrated in Fig. 7.

Fig. 7. Extended Risk-Based Approach: Securing Physical or any Emerging Technology throughout its life-cycle

In this framework, in addition to the Risk-Based Approach described in earlier research, every device would follow a process for risk evaluation throughout its life-cycle and in the case of some technologies, training and configuration questions also fall under scrutiny as elements of risk. This would be linked to budgeting and the ongoing security posture of the firm. This Extended Risk-Based Approach would create a risk eco-system as enterprise architecture develops. The advantage is that budgets are built with life-cycle risk in mind as well as the interaction of cyber risk exposures in an ecosystem. This would be coupled with and amplify the user-behavior analytics and cross-discipline monitoring which is part of the original approach. Furthermore, this approach builds on the SD theory, potentially incorporating risk into the modelling of the relationships at all three levels described in this theory.

From these discussions, the extended risk-based approach was taken back to the companies and executives who helped develop it. They then provided a higher-level set of questions to drive a risk-based process to consider at the board level. This board level approach is modeled after the board approach used in a global medical device company and is presented in Fig. 8 below:

Fig. 8. Board level process for considering cyber-physical risk

Finally, a list of questions that boards should ask emerged from the interviews and discussions. These are listed below:

1. Have we established an appropriate cyber-physical risk escalation framework that includes our risk appetite and reporting thresholds?
2. How do our cyber-physical security program and capabilities align to the current cyber-physical standards developed by NIST and DHS as well as peer organizations? What more can we be doing beyond these standards?
3. Do we have an organization-wide mindset and cyber physical risk conscious culture?
4. What has our executive team done to protect the organization against third-party cyber risks?
8. Can we rapidly contain damages and mobilize diverse response resources should a cyber-incident occur?
9. Are we helping to protect our industry, and the nation against cyber risks by taking a broad approach to knowledge and information sharing?
10. Do we possess the right trusted advisors and cross functional teams to support the Board level process in the extended risk-based approach?

Cyber-physical systems are still rapidly emerging as evidenced by the data presented in this research. Therefore, there aren't many established standards yet even as the number of applications brought to market is quickly rising. Given that these standards are emerging, tracking and adhering to standards developed (by ISO, NIST and others) as they evolve is critical. As a result of these emerging systems dynamics, there is a strong need for adopters to carefully plan and build in security throughout the life-cycle of emerging technology deployment as indicated by the Extended Risk-Based Approach presented here.

5. Conclusion

This research explored the deployment of emerging technologies and the implications for cyber-physical security at the executive oversight and board level. The focus was on examining what is happening in business to provide a practical approach for business leaders to follow in securing this new interconnected digital landscape. Then to provide a broad approach and even a board process so executives and teams could begin to tackle the new cyber-physical reality while standards continue to develop. This work identified a holistic theoretical approach that resonated with business practice. Our findings indicate that Systems Dynamics theory is a strong foundation for building-out processes for cyber-physical security because there is a constant dynamic addition to the attack surface and ongoing systems behavior is based largely on the time-trajectory of these changing system variables. These findings are consistent with the arguments in [3] and [4] that enterprise risk is an optimal control problem not a max-min problem requiring ongoing project and process risk evaluation across the enterprise. These results extend the application of theory and provide new optics for considering enterprise risk from for not only protecting the bottom-line but adding to the top-line as part of a dynamic system. Furthermore, this approach was the foundation for the Extended-Risk Based Approach model presented which places the life-cycle management process at the center of risk evaluation. The quantitative results showed that more businesses are taking a Risk-Based Approach and that there is greater board oversight. It also showed that cyber-physical systems are rapidly being deployed but still in the early stages of deployment. This is an important transition in cyber-physical risk from just being part of the IT function to being a consideration across the enterprise which, indeed, is where it belongs. The qualitative research built on these results to develop an extended

approach through conversations with business leaders and executives to arrive at a broad life-cycle approach as well as a process for board oversight. In this regard, key questions that board members should ask were distilled. This is not an exhaustive list of questions, but rather a solid place to start. Future research can delve into specific industry segment cyber-physical risks as well as the development of appropriate standards and controls. The Extended Risk-Based Approach was coupled with some very specific recommendations from business executives and boards to provide some high-level tools. This study provides a process and approach for business executives and board members to use in order to provide oversight for cyber-physical risk as companies continue to deploy emerging technologies.

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Video Advertising: Connection and differences between consumers?

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Abstract. The internet search trend has caused that online user are looking for more and more enriched information. The evolution of social media has been huge and users relate to social networks differently than they did before. Currently, there are more than 4 billion active users on social networks and brands are looking to showcase their products and services. Our research found the following factors that influence social media engagement: informativeness, self-connection and advertising stimulation. Through literature review, we propose a conceptual model that has been tested in the PLS-SEM. Data were collected from 237 consumers and our survey found that engagement in social media is explained by the variables identified by our model. Important contributions to brand theory and management will be found in this investigation.

Keywords: Social Media Engagement, Video Advertising, Self Brand Connection.

1. Introduction

In recent years, the rapid expansion of the use of social networks by increasingly heterogeneous audiences have brought new challenges and opportunities in the area of advertising. The use of advertising videos for social networks in marketing strategies increasingly create engagement with the brand.

Compared to other advertising formats, videos have the possibility of becoming more personal, using creativity to optimize interaction with the public and achieve commercial goals. For that and according to Escadas [1] ads should not be only persuasive, but they must have an affective component that directs to the consumer unconsciously. Structurally, narratives must be based on a plot with incidents and surprises, on characters to whom conflicts, and events take place and at a climax moment where the resolution of the story is presented [2] and the greater conflict finally resolved. In addition, the symbiosis between the structure of the narrative and the elements of the story creates a powerful tool for transmitting information [3] and, when created effectively, allows for more favorable cognitive responses, warm feelings and positive attitudes of the narrative ad, when compared to argument advertising [4].

On the other side, consumers tend to purchase brands and products similar to them, that coincide with their ego and they could build a brand-consumer emotional relationship [5]. Consumer engagement plays a central role in social media marketing strategies, however further research is needed [6] because studies in this topic are limited [7]. In this study we analyze self-brand connection, informativeness and advertising stimulation as predictors of social media engagement on video advertising.

2. Literature Review

2.1. Advertising informativeness and stimulation

Technological innovation is the new context in which advertising campaigns must invest to impact the consumer. Advertising gained power, but also the responsibility to respond to the new consumer who is looking for novelty and low tolerance to consume more of it.

The direct and immediate function of advertising, which is a communication force between the product and the public, is not just to make the purchase take place.

The direct and immediate function of advertising, which is a communication force between the product and the public, is not just to make the purchase take place. Of course, it contributes to this, but its specific objective is to act on the public's state of mind and lead them to purchase [8]. Establish favorable conditions for consumption, create attributes so that, even after the purchase, the consumer feels privileged by the choice. Advertising objectives, dependent on those of marketing, respond to three established basic needs: to inform, persuade and remember [9].

According to Lee and Hong [10], the informativeness of ads is as important as creativity, often emphasized in public literature, they reveal themselves to be the main drivers of behavior favorable to advertisements on social networking services, promoting purchase intentions.

Ducoffe, in 1996, defines advertising informativeness as the ability of advertising to inform consumers about alternative product information, which can create a balance between the offers of producers in relation to the needs of consumers, creating a more efficient market. Schlosser, Shavitt and Kanfer (1999) state that there is even a positive relationship between consumers' attitudes towards advertising with informative characteristics, made on the Internet [11].

On the other hand, advertising campaigns also have more specific objectives, such as helping to introduce a product to the market, maintaining the market, informing about new products and their use, selling the brand image, among others. To achieve these goals, and in digital contexts, advertisers are integrating social media in planning advertising strategies in order to boost digital engagement as well. For Hilde, Noort, Muntinga and Bronner [12], one of the important variables in the analysis of this involvement is the stimulation that advertising can offer. Here, the analysis of the enthusiasm of the recipients and the seduction and originality of advertising is valued through informativeness. Therefore, a clear awareness of these variables and of public needs is fundamental to the success of an advertising campaign. Thus, we proposed the following:

H1: Informativeness has positive effects on advertising stimulation

2.2. Self-Brand Connection

Brands represents who consumers are or want to be, as their life projects, goals or personal concerns [13], are perceived as brands with personality and congruent to their own personality [14].

Consumers tend to prefer brands and products that corresponds to their self-image and ego, which is an important factor in emotional relationship between consumers and brands [15].

The concept of brand-self connection derived from 'Self-Expansion Theory' and it is formed by consumers when conceptualize their self into brands to others [13]. In this way, self–brand connection is a crucial dimension of the consumer–brand relationship

[14] and it is defined by Escalas and Bettman [16] as "the degree to which consumers have incorporated the brand into their self-concept".

Park et al. [14] conceptualize brand attachment in two dimensions: self-connection and prominence. While self-connection is the expression of individuals their selves similar to brand personality, brand prominence is the easiness and frequency that brand brought into consumers' mind [14].

Brands are used by consumers to express their self-concept and identity, allowing differentiation from others and express of individuality [17].

Both individual connections and group connections contribute to Consumer–brand relationships [16] as they form consumer's personal identities [18]. The use of each brand and its associations is a way of individuals express their self-identity and satisfying belongingness in reference groups [19].

When consumers have a high self–brand connection also have a higher tendency to engage, refuse negative information about brand and show positive WOM [17]. As brand image and consumer's ego image coincide it increases the intention to purchase brand and positive evaluations about it [20].

Thomson et al. [19] demonstrates that brand attachment has consequences for brands such as brand loyalty [20] and the willingness to pay a price premium. It is also reflected in emotional responses, brand responsiveness [24], commitment [23] and minimization of the effects of negative information or unethical firm behavior [22]. Therefore, we analyze advertising stimulation as an emotional response. Thus, we propose the following:

H2: Self-brand connection has positive effects on advertising stimulation.

2.3. Social Media Engagement

In recent years, brands have seen changes in the way consumers interact and get engaged especially through social media [25]. Calder, Isaac and Malthouse [26] consider consumer engagement as "a multilevel, multidimensional construct that emerges from the thoughts and feelings about one or more rich experiences involved in reaching a personal goal". As antecedents of consumer engagement in social media are pointed out: consumer involvement [27] and consumer participation [29].

Costumers' engagement in social media is showed also "liking" a brand on Facebook, it means that individuals consider that brand as part of their online self-expression [30]. Social media is used by consumers to engage with brands, present an "ideal-self", and build positive self-images [31].

Thus, brands must create strategies on social media that promote relevant and frequent content as well as incentives for consumer participation [32].

Engagement in social media also depends on the platform, while Facebook is considered easy-to-use and engaging [33], YouTube has less interactivity, and Instagram and Pinterest due to visual appearance provides instant feedback and comments [34].

This engagement is expressed through likes, comments or shares in brand's posts that reflect cognitive, affective and behavioral aspects [35]. According to the Consumer Online Brand-Related Activity (COBRA) model proposed by Muntinga et al. [35] engagement can be: low (users just consume content, viewing videos and pictures, have a passive posture - lurkers), medium (users contribute, comment on posts, etc.) or high (users share and create content about the brand).

The type of posts also influences interaction, a study by [36] shows that informational posts generate more likes, comments and shares preconsumption stage while entertainment posts generate more interaction in the postconsumption stage. Building trust among users is also fundamental to fostering engagement with brands on social media [37].

In a study about advertising and engagement with social media platform, Hilde et al. [12] demonstrated that engagement is highly context specific, it depends on the experience in each platform, i.e, people evaluate advertising differently depending on the platform used and not just the ad content. Engagement with the medium or platform influences responses and engagement with advertising [29].

Engagement has several consequences for brands, and numerous studies have pointed out this [38] [39] [40]. It has impacts on brand loyalty [39] [40], brand awareness [38], commitment [41], trust [42] and perceived quality [38].

In social media, some studies demonstrated that engagement also increase brand performance [43] and influence purchase decisions and sales [44] [45].

Several studies also confirm that people high engaged can be more responsive to brand advertisements [46]. Consequently, we propose to test the following research hypotheses:

H3: Self-brand connection has positive effects on social media engagement

H4: Advertising stimulation has positive effects on social media engagement

Based on the previous information, our study aims to test the following conceptual model (see Fig. 1).

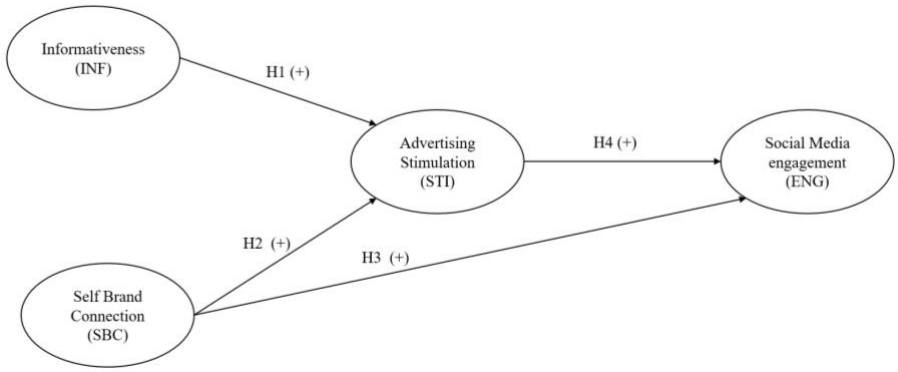

Fig. 1. Conceptual model [38-40].

3. Method

The proposed model was validated with collected data through a self-administered survey. The survey was conducted among Staples' brand consumers. Staples Inc. was founded in 1986 and this company is the world's largest network of office stores. The survey had two phases. First, we presented an advertising video to the participants, and after, we ask about the video and about the brand.

The construct was measured through previous items used in literature. The measured items for informativeness follow used items from Jeon, Lee and Hong [47]. We measured self-brand connection through items employed by Jeon, Lee and Jeong [47]. The construct advertising Stimulation was measured by items from Voorveld, van Noort, Muntinga and Bronner [37]. Finally, we measured social media engagement through Schivinski and Dabrowski [28]. All the items used in this study were measured using a 5-point Likert scales, ranging from strongly disagree (1) to strongly agree (5).

Sample

Before we present the estimate model results, we show the sample which has 237consumers. On table 2 we show that 59.5% are female and most of the observations (N = 185; 78.1%) and originated from individuals below 40 years old. Many of them (N = 134; 56.5%) have primary or secondary school qualifications (Table 1).

Table 1. Demographic profiles (N=237)

Variables	Category	N	%
Gender	Male	96	40.5
	Female	141	59.5%
Age	≤ 20	69	29.1%
	20 - 29	97	40.9%
	30 - 39	19	8.0%
	40 - 49	27	11.4%
	≥ 50	25	10.5%
Education	Primary school studies	18	7.6%
	Secondary school studies	116	48.9%
	High School	103	43.5%

4. Results

The estimation of the conceptual model followed the methodology through Partial Least Squares - Structural Equation Modeling (PLS-SEM). The PLS-SEM allows researchers to analyze causal relationships between constructs and is suitable for exploratory research and does not require data normality [49]. Furthermore, the PLS-SEM is robust enough for small samples.
PLS-SEM is performed in two steps. In the first step we analyze the reliability and validity of the measurement model and, secondly, we analyze the relationships between the constructs, as suggested in literature [49]. We ran PLS-SEM on SMART PLS v3.3.2.

Common Method Bias

Responses were collected from the same respondents and, there was a possibility of common method bias. First, we performed Harman's one-factor test [50] with factor one representing 30.52% of the variance. Furthermore, we carry out a preliminary data analysis to validate VIF – Variance Inflactor Factor. VIF values are ranged between 1.393 and 3.286 which is below the threshold value (VIF <5). Therefore, there is no multicollinearity. Thus, common method bias would not be a concern. Moreover, we analysed the Skewness (Sk) and Kurtosis (Ku), which reveal that the items do not diverge from normality (Sk <3; Ku <7) [51].

Measurement Model

On first step of PLS-SEM we analyzed the measurement model and confirmed that the constructs have validity and reliability. Additionally, we con-firmed that the standardized loadings (λ) are higher than the minimum value of 0.7. The reflexive constructs of the model have an average extracted variance above 0.5 and composite reliability above the minimum value of 0.7. Table 2 shows the results obtained for the measurement model. [52], which are acceptable for further analysis.

Table 2. Items, Descriptive Statistics, and coefficient loadings (N=237)

	Mean	SD	λ	*t* values	*p* values
Informativeness (α =0.905; ρA=0.905; CR=0.934; AVE=0.778)					
INF01	3.36	0.910	0.859	39.000	0.000
INF02	2.82	1.160	0.819	33.462	0.000
INF03	3.34	0.980	0.904	57.152	0.000
Self Brand Connection (α =0.826; ρA=0.826; CR=0.896; AVE=0.742)					
SBC01	2.22	1.075	0.890	46.568	0.000
SBC02	2.55	1.209	0.887	42.610	0.000
SBC03	2.53	1.174	0.900	46.472	0.000
SBC04	2.29	1.162	0.885	42.637	0.000
Advertising Stimulation (α =0.913; ρA=0.922; CR=0.939; AVE=0.793)					
STI01	3.13	1.063	0.786	27.536	0.000
STI02	2.77	1.113	0.773	21.754	0.000
STI03	3.50	1.060	0.701	12.686	0.000
STI04	3.01	1.169	0.726	16.921	0.000
STI05	2.67	1.086	0.874	60.179	0.000
Social Media Engagement (α =0.820; ρA=0.845; CR=0.874; AVE=0.583)					
ENG01	2.50	1.174	0.857	37.282	0.000
ENG02	2.06	1.106	0.908	58.753	0.000
ENG03	2.31	1.170	0.880	39.287	0.000
ENG04	2.22	1.156	0.883	36.732	0.000

Note: All items are measured with a 5 point Likert Scale ranging between (1) strongly disagree and (5) strongly agree
SD= Standard Deviation; *α*=Cronbach's Alpha; λ =Standardized Loadings; AVE= Average Variance extracted; CR= Composite Reliability; INF=Informativeness; SBC= self-brand connection; STI= Advertising Stimulation; ENG= Social Media Engagement.

Table 2 also shows that Average Variance extracted (AVE) (ranging from 0.583 to 0.793) and composite reliability (CR) (ranging from 0.874 to 0.939) are above the threshold values (AVE>0.5; CR>0.7) [53]. These values showed convergent validity and reliability for all constructs. To validate the measurement model, the analysis of discriminant validity is an essential step. In our study, we analyzed discriminant validity using three methods. Discriminant validity was confirmed in three ways.

Firstly, we present the data obtained to verify the Fornell and Larcker criterion [54] (Table 3). The results obtained suggest that the correlations between the latent variables are below the values of the square root values of the AVE (Table 3).

Table3. Discriminant validity: Fornell and Larcker criterion [54]

	ENG	INF	SBC	STI
ENG	0.882			
INF	0.548	0.862		
SBC	0.544	0.442	0.890	
STI	0.674	0.679	0.584	0.764

INF=Informativeness; SBC= self-brand connection; STI= Advertising Stimulation; ENG= Social Media Engagement.

In the second step, we analyzed the Cross-Loadings values (Table 4) [55]. Table 4 confirms that, for all items, cross-loadings with other constructs are below than standardized loadings (λ).

Table 4. Cross-Loadings

	ENG	INF	SBC	STI
INF01	0.436	0.859	0.353	0.553
INF02	0.550	0.819	0.428	0.619
INF03	0.422	0.904	0.355	0.575
SBC01	0.576	0.436	0.890	0.557
SBC02	0.397	0.352	0.887	0.456
SBC03	0.445	0.403	0.900	0.477
SBC04	0.492	0.374	0.885	0.570
STI01	0.522	0.446	0.457	0.786
STI02	0.509	0.470	0.491	0.773
STI03	0.319	0.353	0.303	0.641
STI04	0.476	0.624	0.411	0.726
STI05	0.673	0.638	0.529	0.874
ENG01	0.857	0.524	0.497	0.605
ENG02	0.908	0.467	0.504	0.572
ENG03	0.880	0.460	0.449	0.622
ENG04	0.883	0.481	0.468	0.576

INF=Informativeness; SBC= self-brand connection;
STI= Advertising Stimulation; ENG= Social Media Engagement.

The third way we used to assess discriminant validity was the examination through the Heterotrait-Monotrait correlation ratio (HTMT). In Table 5 we confirm that all HTMT values are below the threshold value of 0.9. and, therefore, discriminant was established between latent variables [55]

Table 5. Discriminant validity HTMT ratio [55]

	ENG	INF	SBC	STI
ENG				
INF	0.630			
SBC	0.589	0.503		
STI	0.760	0.804	0.657	

INF=Informativeness; SBC= self-brand connection;
STI= Advertising Stimulation; ENG= Social Media Engagement.

Structural Model

In the second step in the PLS-SEM we examined the structural model and the causal relationships between variables. To analyze the model fit we obtained the SRMR = 0.076, which is below than the threshold value [56]. Next, we divided our sample in two groups of consumers: female and male. Next, we analyzed the adjusted R^2 of the endogenous variables in our model (Table 6).

Table 6. Adjusted R^2 of the endogenous variables

Group	STI	ENG
Female	0.530	0.384
Male	0.604	0.632

STI= Advertising Stimulation; ENG= Social Media Engagement.

The structural model aimed to test the results of the hypothesis test and we examined the results obtained in the male (Table 7) and female (Table 8) consumer groups.

Table 7. Hypotheses testing (group: female)

Path	β	*t* values	*p* values	95% confidence interval	Hypothesis
INF à STI	0,531	8,410	0,000	[0,390 .. 0,640]	H1: Supported
SBC à STI	0,347	5,742	0,000	[0,234 .. 0,476]	H2: Supported
SBC à ENG	0,215	2,549	0,011	[0,051 .. 0,382]	H3: Supported
STI à ENG	0,478	7,308	0,000	[0,336 .. 0,591]	H4: Supported

β =Standardized path coefficients; INF=Informativeness; SBC= self-brand connection; STI= Advertising Stimulation; ENG= Social Media Engagement

Table 8. Hypotheses testing (group: male)

Path	β	*t* values	*p* values	95% confidence interval	Hypothesis
INF à STI	0,508	6,918	0,000	[0,355 .. 0,641]	H1: Supported
SBC à STI	0,370	4,511	0,000	[0,200 .. 0,525]	H2: Supported
SBC à ENG	0,199	2,014	0,044	[0,008 .. 0,394]	H3: Supported
STI à ENG	0,651	7,621	0,000	[0,474 .. 0,804]	H4: Supported

β =Standardized path coefficients; INF=Informativeness; SBC= self-brand connection; STI= Advertising Stimulation; ENG= Social Media Engagement

The hypotheses were examined by assessing the significance of path coefficients, and we used a bootstrapping procedure with 5000 subsamples.

Hypothesis H1 examines causality between informativity and advertising stimulation. In both male and female groups, we confirm that the relationship exists and the results indicate that, for $p<0.001$ informativeness positively influences advertising stimulation.

Therefore, we concluded that informativeness has substantial positive effects on advertising stimulation.

The investigation also examined the influence of the self-brand connection on advertising stimulation. In both groups of Staples brand consumers analyzed, we confirmed this research hypothesis and found that high levels of self-brand connection influence advertising stimulation. Thus, we corroborate hypothesis H2 in our study.
Hypothesis H3 is also confirmed in our study, since the results obtained for the female group ($\beta_{SBC \rightarrow ENG} = 0.215$; $p < 0.05$) and for the male group ($\beta_{SBC \rightarrow ENG} = 0.199$; $p < 0.05$) verify the existence of causality between the variables.

Finally, H4 proposes that advertising stimulation positively influences social media engagement. Our results show that this path is significant in both groups. female ($\beta_{STI \rightarrow ENG} = 0.478$; $p < 0.01$) and male ($\beta_{STI \rightarrow ENG} = 0.651$; $p < 0.01$).

5. Conclusions

Nowadays, brand communication goes through actions on social networks. The capture of new audiences and the improved segmentation allow communication through social networks to be more effective than in other media. However, the challenges that arise for brands are new and academic research seeks to identify how consumers move in the digital channel.

The investigation we carried out sought to identify engagement in social networks through the presentation of an advertising video, since this form of communication optimizes the interaction between consumers and brands through creativity, informativeness and self-connection with brands.

Theoretical Implications

This investigation tested the proposed conceptual model and found relevant effects among the variables studied. The results demonstrate that the conceptual model presented better fits the male group compared to the female group. Following Hilde, Noort, Muntinga and Bronner [12], we found significant effects to pro-pose that informativeness influences enthusiasm and emotional stimulation of an advertising video in male and female consumers.

This study additionally observed that the self-brand connection has a decisive position in advertising stimulation. This conclusion is reflected in the literature since higher values of self-brand connection translate into emotional responses to brand advertisements [22].

In this study on advertising, Hilde et al. [12] found that social media engagement depends on previous experiences. This study also found that self-brand connection and advertising stimulation influence social media engagement.

Implications for management

Evidence from this study demonstrates that the informativeness of advertisements is an important ingredient for consumers to engage with video advertisements. Furthermore, our study reports that the self-brand connection is a predictor of advertising engagement.

Therefore, brands must recognize that the information presented in their ads has consequences, and one of those consequences is social media engagement.

Our study also considers that congruence with consumers in order to promote the self-brand connection is a dimension that companies should take into account.

This study also suggests that advertising videos on social media must be original and unique in order to create something new in consumers that generates advertising stimulus and higher values of engagement on social media.

Limitations and future research

This investigation has demonstrated that social media engagement is predicted by informativeness, self-brand-connection and advertising stimulation in different audiences (female and male). In general, the variables identified in conceptual model explain the social media engagement, although the explanation is better in the male group. Therefore, brands must understand the determinants identified in this investigation as causes for social media engagement [58, 59].

It is crucial to point out the constraints of our investigation. First, the composition of the sample in terms of age and education may have influenced the results obtained and the groups dimension must be higher. Second, the presentation of a particular message video ad could have affected our results. Third, our inferences must be considered from a transversal point of view.

In this way, it will be appropriate to expand future research on social media engagement [60]. Consequently, we suggest that additional studies should be carried out, with samples different and higher. Additionally, it will be appropriate to carry out researches that explore advertising videos from other brands. In addition, we suggest that longitudinal investigations can be carried out to recognize the advancement of social media engagement over time.

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Mobility Assistants to Support Multi-Modal Routes in Smart Cities: A Scoping Review

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Abstract. Objectives - This study aimed to identify: (i) the current research trends related to mobility assistants to support multi-modal routes in smart cities; (ii) the types of smart cities' data being used; (iii) the methods applied to assess the proposed solutions; and iv) the major barriers for their dissemination. Methods - An electronic search was conducted in several databases, combining relevant keywords. Then titles and abstracts were screened against inclusion and exclusion criteria. Finally, the full texts of the eligible articles were retrieved and screened for inclusion. Results - A total of 19 articles were included. These articles either propose algorithms to optimize routes planning or presenting specific applications that make use of a broad range of smart cities' data. Conclusion - The number of included articles is very reduced when compared with the total number of articles related to smart cities, which means that the mobility assistants to support multi-modal routes are still not significant within the smart cities' research. Moreover, most of the included articles report applications in an early stage of development, which is a major barrier for the respective dissemination.

Keywords: Smart cities, Smart mobility, Mobility assistants, Scoping review.

1. Introduction

Since a significant percentage of the world population live in urban areas (e.g., almost three-quarters of the European population live in urban areas [1]), cities have reinforced their role as dominant centers of population and infrastructures. As such, cities are crucial in generating economic value and providing social environments, but also present a broad range of difficulties (e.g., scarcity of resources, pollution, and traffic congestion), due to the population aggregation.

The recent technological evolution has shaped the advent of a range of urban discourses, such as the creative city, the sustainable city, the knowledge city, the

educating city, and the intelligent city [2], all of them aiming to ensure livable and competitive conditions to face new expectations and ambitions to grow and succeed socially and economically.

The concept of 'Smart Cities' emerges in this context and its importance is emphasized by scientific journals publishing specific issues on this topic, local governments fighting to label their city as such, firms, particularly in the information technologies (IT) field, advertising smart cities' solutions, and research initiatives funded by international programs aiming to promote adequate implementations [3]. Moreover, smart cities' rankings have been established, both directed at metropolitan areas [4] and medium-sized cities [5,6]. Due to such rankings, cities are increasingly challenged to raise their levels of competitiveness.

In the political arena, the smart cities' label has also been forcefully grasped, not only by various local, regional, and national governments, but also by wider scale levels. This is shown by Manville and colleagues [7] and several initiatives of the European Commission, namely the Digital Agenda (one of the seven pillars of the Europe 2020 Strategy) and the Smart Cities and Communities initiative, aimed at bringing together cities, industry, and citizens through more sustainable integrated solutions [8]. In the European Union (EU), for instance, the Amsterdam Smart City is a known example of a unique partnership between businesses, authorities, research institutions and citizens with the aim of creating an infrastructure for knowledge exchange and learning between all these actors [9]. Smart Santander [10] is another awarded and similar example that was financially supported by the EU 7th framework program and led by the R&D department of Telefónica, a major telecommunications operator, and the University of Cantábria, with the regional government and the city council as partners.

Smart cities promote the integration of traditional urban infrastructures and IT and can be seen as cities capable of collecting and analyzing vast quantities of data, through low-cost sensors, data-actuated devices, and wireless communication networks, which are required by automated and intelligent processes (e.g., advanced data analytic) [6,11]) to improve the quality of the city services.

A set of characteristics have been identified as relevant in the context of smart cities [11-13]: (i) smart economy, competitiveness of the economy, which is influenced by factors such as innovative spirit, entrepreneurship, ability to transform or integration in the international market; (ii) smart mobility, local, national, and international accessibility, and the availability of communication infrastructure or sustainable and safe transport systems; (iii) smart governance, political strategies and perspectives, transparent governance, participation of the individuals in public life, and the quantity and quality of public services; (iv) smart environment, the ecological awareness and sustainable management of natural resources including environmental conditions such as air quality; (v) smart people, social and human capital such as the level of qualification, fostering lifelong learning, ethnic plurality, and open mindedness; and (vi) smart living, quality of life of the individuals, namely health conditions, cultural and education facilities, housing quality, and touristic attractiveness.

Urban mobility is related to the movement of individuals, both obligatory (e.g., home-to-work trips) and voluntary (e.g., leisure), with the goal of accessing desired destinations. It depends not only on the available transportation, but also of other characteristics, such as locations of both activities and households, physiological, intellectual, and socioeconomic needs of the individuals, purpose of the movement, movement length or travel time distribution [14,15]. According to the current concepts of multi-modal urban mobility, public transportation should be combined with other motorized (including small size electric vehicles) and non-motorized modes (also known as active transportation, such as walking and bicycling), as well as with new forms of vehicle ownership (e.g., car sharing or ride sharing) [16].

Within the smart cities' paradigm, smart mobility [17] is aligned with the United Nations (UN) Sustainable Development Goals [18] and is often seen as related to the use of IT to adequately orchestrate services designed to improve urban mobility [15]. In this respect, a wide range of information services can be foreseen, such as intelligent transportation systems [19-23] or algorithms to infer mobility patterns [24,25]. These information services might contribute to the reduction of air and noise pollution, traffic congestion, and travel costs, while increasing people safety [15,26,27].

Systematic reviews of the literature related to the implementation of smart cities are scarce and address specific aspects (e.g., [11,28,29]). Systematic reviews allow not only to answer clearly formulated questions, using systematic methods, but also to critically evaluate and synthesize results from multiple primary studies, thus consolidating knowledge and identifying gaps in a given research field. Therefore, systematic reviews of the literature can provide the evidence that is required to inform smart cities' stakeholders and researchers about state-of-the art solutions.

This article complements the results published in [30] and reports a scoping review to systematize scientific evidence related to mobility assistants to support multi-modal routes in smart cities. The following sections present the plan of the scoping review, its results and a discussion and conclusion.

2. Methods

For the specific objective of the scoping review reported by this article the following research questions were formulated:

- RQ1: What are the current research trends related to mobility assistants to support multi-modal routes in smart cities?
- RQ2: What types of smart cities' data are being used?
- RQ3: What methods were used to assess the solutions being reported?
- RQ4: What are the major barriers for the dissemination of the results?

Boolean queries were prepared to include all the articles that have in their titles, abstract or keywords one of the following expressions: 'Smart City', 'Smartcity', 'Smart-city', 'Smart Cities', 'Smartcities' or 'Smart-cities'. The resources considered to be searched were two general databases, Web of Science and Scopus. The literature search was concluded in April 2021 and aimed to include all articles published before 31st of March 2021.

As inclusion criteria, the authors aimed to include all the articles that report contributions for the development of mobility assistants to support multi-modal routes in smart cities.

Considering the exclusion criteria, the authors aimed to exclude all the articles not published in English, without abstract or without access to full text. Furthermore, the authors also aimed to exclude all the articles that report overviews, reviews, or solutions that do not explicitly require smart cities' infrastructures, as well as article reporting studies not relevant for the specific objective of this scoping review.

The analysis and selection of the articles were performed in three steps:

- First step - the authors removed the duplicates, the articles without abstract and that were not written in English.
- Second step - the authors assessed all titles and abstracts for relevance and those clearly not meeting the inclusion and exclusion criteria were removed.
- Third step - the authors then assessed the full text of the remaining articles against the outlined inclusion and exclusion criteria and created the final list of the articles to be considered for the review.

Throughout this entire process, all the articles were analyzed by at least two authors and any disagreement between the authors was discussed and resolved by consensus.

3. Results

Fig. 1 presents the flowchart of the scoping review.

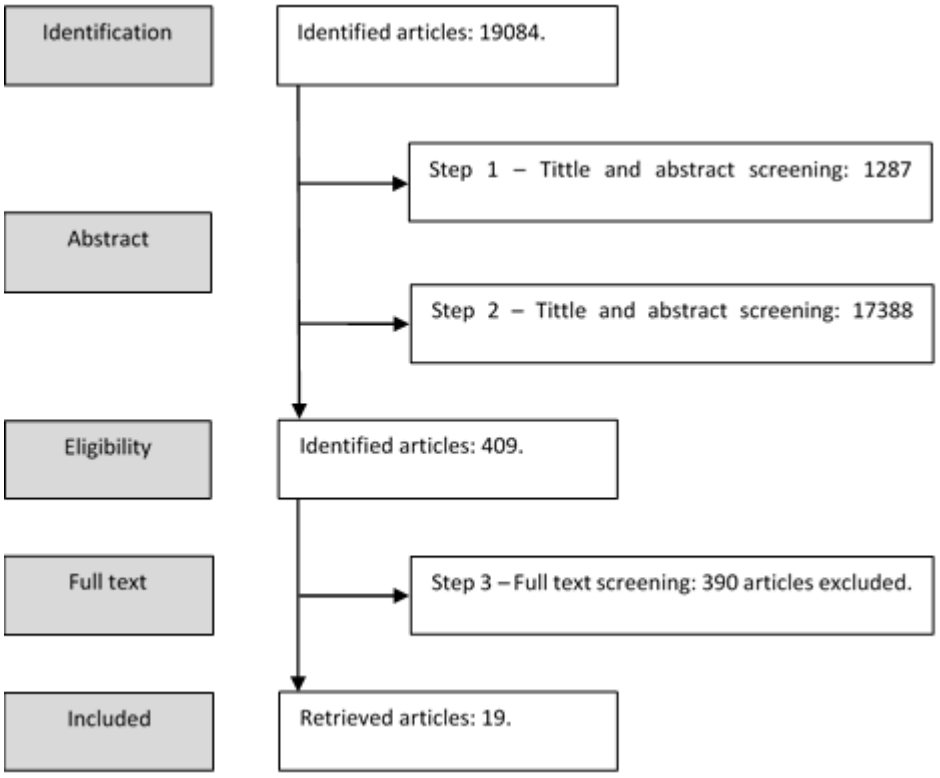

Fig. 1. Review flowchart

A total of 19084 articles were retrieved from the initial search on Web of Science and Scopus. The initial step of the screening phase yielded 17797 articles by removing the duplicates or the articles without abstracts. Based on abstracts, 5689 articles were removed since they were not published in English, or they are overviews or reviews, editorials, prefaces, and announcements of special issues, workshops, or books. Moreover, 11699 articles were removed because they were out of scope of the objective of the scoping review being reported. Among the excluded articles, several articles were related to smart mobility, but they target other topics rather mobility assistants to support multi-modal routes in smart cities. For example, impaired mobility (e.g., [31,32]), prediction of mobility patterns (e.g., [33,34]) or assistance to drivers (e.g., [35,36]).

Finally, the full texts of the remaining 409 articles were screened and 390 articles were excluded because they do not meet the inclusion criteria. Therefore, 19 articles were considered eligible for this scoping review.

All the included articles intend to contribute for the development of mobility assistants to support multi-modal transportation situations using smart cities' infrastructures. However, according to their proposes, the included articles were divided into two classes (Table 1):

- Algorithms - algorithms that can be used by mobility assistants [37-41].
- Mobility assistants - development of specific applications to support multi-modal routes in smart cities [42-55].

Table 1. Aims of the retrieved studies.

Classes	Reference	Title	Aim of the Study	Year
Algorithms	[37]	Optimal journey planning depending on distance and passenger density parameters.	To propose a method for planning optimal routes considering both the distance from origin to the destination and the passengers' density of public transportation.	2013
	[38]	Improving mobility in smart cities with intelligent tourist trip planning.	To propose a two steps algorithm to provide tourists with safe and efficient itineraries considering mobility policies.	2017
	[39]	Crowd-based ecofriendly trip planning.	To present algorithms that incorporate dynamic transit schedule data while balancing the availability of bikes among the bike stations	2018
	[40]	A distributed approach based on transition graph for resolving multimodal urban transportation problem.	To propose an approach of assistance taking advantages of multimodal urban transportation means, which is based on an abstraction of a city multimodal graph.	2019
	[41]	Game theoretic approach for public multi-mode transportation in smart cities.	To propose an algorithm based on the game theory for the optimization of multi-mode transportation routes.	2020
Mobility Assistants	[42]	A system for green personal integrated mobility: A research in progress.	To present a mobility assistant that handles end-to-end itineraries that may involve multiple green, shared and public transportation.	2013
	[43]	Depart: Dynamic route planning in stochastic time-dependent public transit networks.	To propose a mobility assistant based on a stochastic time-dependent model for public transportation networks by leveraging a set of historical travel smart card data.	2015
	[44]	Mobility mining for journey planning in Rome.	To present a mobility assistant that considers uncertainty (e.g., delays in time of arrivals, impossibility to board, or walking speed).	2015
	[45]	Next generation of journey planner in a smart city.	To present a mobility assistant that leverages on comprehensive urban data (e.g., traffic network data or real-time traffic speed data), aiming to provide accurate and effective recommendations.	2015
	[46]	Crowdsensing based public transport information service in smart cities.	To present a crowd sensing-based mobility assistant in which the updates of transports schedule information rely on automatic stop event detection of public transportation vehicles using mobile sensing.	2015
	[47]	An architecture for a mobility recommender system in smart cities.	To present a mobility assistant focused on car-based multi-modality, where the users always start the trips with their private vehicle but can also use public transportation to reach the destinations.	2016
	[48]	An internet-of-things enabled connected navigation system for urban bus riders.	To present a mobility assistant able to support micro-navigation and to provide crowd-aware route recommendation.	2016
	[49]	An integrated system for risk-averse multimodal journey advising.	To propose an uncertainty-aware mobility assistant to advise on how to use a given transportation system.	2016
	[50]	A cooperative positioning service for multi-modal public transit situations.	To present a mobility assistant to support micro-navigation of travellers that are unfamiliar with multimodal transportation.	2017
	[51]	A Mobile Application for multimodal trip planning.	To present a mobility assistant that provides a multimodal route solution combining public transportation with carpooling.	2018
	[52]	Toward an interactive mobility assistant for multi-modal transport in smart cities.	To provide a mobility assistant that grounds on an approach for deliberative agents using mental attitudes, in order to overcome the information overload and proactively help travellers.	2018
	[53]	SmartMobility, an application for multiple integrated transportation services in a smart city.	To present a mobility assistant that exploits an ecosystem of devices of a smart city.	2018
	[54]	MMARRS: An intelligent route recommendation and road traffic information system for multimodal and unimodal public transportation using text analysis.	To proposes an intelligent route recommendation and road traffic information application based on traffic-related tweets.	2018
	[55]	Enabling customizable services for multimodal smart mobility with city-platforms.	To propose an intelligent urban mobility solution, where the context-awareness, user preferences, and environmental factors are considered for the route planning.	2021

In terms of publications sources, 13 articles were published in conference proceedings [37-40,42,43-45,47,51-54], five were published in scientific journals [41,46,48,50,55] and one was published as a book chapter [49]. More that the half of the articles were published in the last five years.

3.1. Purposes

3.1.1 Algorithms

The algorithm proposed by article [40] is useful to find optimal routes in a multimodal transportation network composed of a set of mono-modal networks (e.g., tramway, train, or metro), road traffic networks and available parks in a city. The global multimodal network is abstracted into sub-graphs. Contrary to traditional approaches where for the optimal path resolution the multimodal network is considered as a whole, the proposed solution consists of making intermediate calculations for each sub-graph before considering the whole network [40]. Results of the algorithm simulations under MATLAB show that when the global graph is abstracted into sub-graphs, the problem is simplified and consequently the execution time is reduced [40].

Article [37] proposes a method for planning optimal routes considering both the distance from origin to the destination and the passengers' density of public transports. This essentially requires finding the shortest paths for both minimum distance and minimum total density. For that, a two-layer graph model was used. Consequently, the optimal solution is obtained by a two steps process: (i) first, the shortest path is found using conventional methods in the distance graph; then (ii) the solution vector that is found in the first step is used to extract which lines are supposed to be used and at which stop the traveler must transfer in order to travel in vehicles with the least number of passengers.

In turn, article [38] also propose a two steps algorithm, but for a different aim: to provide tourists with safe and efficient itineraries and at same time promoting sustainable mobility in the city by considering mobility policies. The two steps of the algorithm are: (i) transformation of the initial problem to an equivalent arc orienteering problem, where the scores and time costs are associated solely to the routes; and (ii) finding a near optimal solution to the transformed problem [38].

To evaluate the efficiency and accuracy of the proposed algorithm, the authors created a real-life data set related to the City of Barcelona, Spain, containing 800 test instances with different graph topologies. By evaluating the algorithm using this data set, the authors concluded that it finds solutions with accuracy requiring few interactions, which makes it suitable for mobile devices [38].

Article [39] is also focused on a dual optimization problem. The goal is to maximize the number of bike stations that are balanced and to optimize the route planning process by incorporating dynamic real-time data about schedule delays. A modified random-walk method is used to estimate the bike stations' net flow and identify the stations that are unbalanced and for which it is required to either pick-up bike from or drop-off bikes to. In turn, for the route planning the proposed method [39] searches the shortest path from the origin to the destination using the standard cost metrics included in the Open Trip Planner framework.

Two heterogeneous sources of real-world data from the City of Warsaw, Poland, were used to evaluate the proposed algorithm and the authors concluded that the approach might allow the travelers to take advantage of the large number of bike stations located nearby transit stops rather than walking [39].

Finally, article [41] presents the Game Theory Multi-Mode Transport optimization model to determine the best route for the passenger to reach their

destinations in the lowest possible time and for the lowest price depending on the types of vehicles they prefer to ride in. The proposed model was simulated through a real scenario of the City of Ottawa, Canada, and the results show that the model gives the passengers an optimal trip at lower cost and faster time.

3.1.2 Mobility Assistants

The purpose of [52] was to argue how a mobility assistant can overcome great amount of information. The authors proposed an agent based on the Belief, Desire, and Intention model [56] and, according to them, the agent beliefs are retrieved from external services as well as from the mobile device the assistant is executed on, the intentions (i.e., selected plans from the plan database) are also located in the external services and the mobile device, and the desires are encoded in the saved travel routes. However, the authors only present the approach and intended as future work to develop and implement the concept [52].

The study reported in article [42] aimed to develop a mobility assistant to make practically feasible the balancing of efficiency of time, energy, pollution, and cost. The mobility assistant is composed by a smartphone application and a set of web services to gather and interpret relevant sources of data including transports status (e.g., train timetable, train delay, underground load, road traffic and deviation from standard travel time) and data retrieved from social networks, that is handled as a text message (e.g., for the detection of traffic jams or road bumps) [42].

In turn, the aim of the mobility assistant proposed by article [47] is to generate different ranked lists of possible multimodal routes that include also parking spaces. The solution is intended to exploit heterogeneous data sources about the road infrastructure, mainly from third party data providers, such as digital map of the road networks and parking data [47].

Article [46] focuses on the communication framework using Extensible Messaging and Presence Protocol to support the development of a crowd assisted mobility assistant that publishes events resulting from the aggregation and interpretation of real-time public transportation data, including data collected by sensors that automatically detect halt events of public transportation vehicles at the stops.

Considering that popular route planners (e.g., Google Maps) have major drawbacks (e.g., the query results are the same no matter whether the departure time falls in peak or off-peak hours), article [43] reports a study aiming the definition of stochastic time-dependent models that take both travel time and waiting time into account and optimize both the speediness and reliability of routes. The resulting mobility assistant might leverage both dynamic (e.g., historical travel smart card data) and static (e.g., bus travel time and waiting time) data sources to recommend routes adapted to traffic situations.

The mobility assistant present by article [44] intends to consider uncertainties related to the expected arrival time of the different modes of transportation available in a city. Therefore, it is supported by a platform able to handle large volumes of heterogeneous urban data (e.g., public transportation network or real-time public transportation data) to provide dynamic updates [44]. By using open data about public transportation of the City of Rome, Italy, the authors concluded that their approach improves the planning of the routes and reduces average expected travel

time.

The mobility assistant presented by article [49] is also supported by dynamic transportation network updates. For that, the authors defined a knowledge base, the network snapshot, with all the information available about a multimodal transportation network (e.g., real-time updates on the estimated times of arrival or GPS data collected from public transportation vehicles). Similarly, articles [45] and [53] also argue that the aggregation of comprehensive urban data (e.g., real-time traffic data) can optimize the recommendations to travelers.

The aim of the mobility assistant proposed by article [45] is to generate inter-modal trips and compute scores for a final decision. For that purpose, data from different sources, including roads, public transportation, traffic, and weather data, are collected and aggregated [45].

In turn, the mobility assistant presented in article [53] also collects data from different sources, namely real-time traffic, parking space vacancy, public transportation or car sharing data. Some of these data are foreseen to be collected by an ecosystem of Internet of Things (IoT) devices (e.g., traffic sensors that can sense vehicles passing by or installed at open-access parking lots) [53].

The objective of the study reported by article [50] is to support individuals who are unfamiliar with the transfer situation. This can be achieved by the development of a mobility assistant for positioning and navigation considering both the macro and micro (i.e., fine-grained contextual guidance) levels. The authors considered several requirements, including smooth transit (i.e., providing real-time data and indoor navigation guidance for travelers to smoothly transit at stations where they need to change) and indoor modelling (e.g., typical routes from one underground line to another or time-dependent patterns). Furthermore, the authors identified that Wi-Fi and Radio-frequency identification (RFID) are suitable localization techniques for the use case scenario under consideration.

The application proposed by [54] aims to provide, alongside traffic information, the best three route recommendation for multimodal transportation. To determine the best route recommendations, text mining techniques are used to infer information from traffic-related tweets.

Article [48] presents a mobility assistant that uses the IoT paradigm (e.g., real-time interaction of travelers' smartphone devices with public transportation vehicle to sense the presence of on-board passengers) aiming to improve the experience of public transportation usage by providing micro-navigation and crowd-aware route recommendation.

The mobility assistant presented by article [51] aims to combine public transportation with carpooling services. The authors propose a set of layers to represent different transports mode and interlayer which represent the travelling time (by foot) required to transit from a transport mode to another. The Dijkstra algorithm was considered in combination with the graph representing the network. Furthermore, to match travelers to cars during the ride matching process, the authors considered that the car travels from origin to destination along a predetermined optimal route, and travelers need to travel to the closest possible stop.

Article [55] reports the development of a city platform to provide customized services for multimodal smart mobility. The platform can aggregate static information related to the transports' infrastructures together with users' context and real-time data provided by different types of sensors, namely air quality sensors, noise monitoring sensors, smart streetlights sensors or sensors to determine the availability of parking slots.

3.2. Types of Data Being Used

Since the objective of smart cities' technological platforms is to promote

automated and intelligent processes based on the analysis of vast quantities of data, the data gathering is an important issue of the proposed applications.

All the included articles considered the integration of the scheduled data of public transports (Table 2). However, this type of data is the only one that is common to the different mobility assistants being reported. In fact, the proposed mobility assistants make use of a wide range of data sources, including transport infrastructures (e.g., roads, parking services), availability of shared transport means (e.g., shared bikes or cars) and real-time status of the different transportation systems (e.g., status of the traffic or public transports). Moreover, some articles report the use of data that are not related to the transports (e.g., environmental data or crowd data from social networks).

Table 2. Types of data being used by the proposed applications.

	[42]	[43]	[44]	[45]	[46]	[47]	[48]	[49]	[50]	[51]	[52]	[53]	[54]	[55]
Transport infrastructures														
Roads	x			x		x		x				x		x
Parks	x					x		x			x	x		x
Public Transports														
Scheduled data (e.g., trains, buses, and underground)	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Availability of shared transports		x								x	x	x		x
Real-time transport data														
Real-time traffic data														
Traffic sensors				x								x		x
Vehicle data from bus, trains, cars, bikes	x													
Probing vehicles which roam the city and report their location and speed in real-time				x										
Other information systems	x			x							x			x
Parking availability	x					x		x			x	x		x
Real-time data of public transports	x	x	x	x	x		x	x	x		x			x
Shared transport data	x							x		x				x
Environmental data														
Weather forecast	x			x							x			x
Air pollution											x			x
Noise pollution														x
Crowd data (alarms and messages coming from social networks)	x					x							x	x
City policies and regulations						x								
Touristic features											x			

Important challenges arise from the diversity of such data [42]. Being involved a wide range of data holders, a universal integrated access may result hard: (i) transport data are often locally stored, thus creating disperse repositories; (ii) legacy systems prevent adoption of open standards and hamper interoperability; and (iii) exclusive access to transport data might be seen as a competitive advantage.

3.3 Validation Methods

In what concerns the articles reporting algorithms that can be used by mobility assistants to determine optimized routes, only one article (i.e., article [37]) does not report any assessment, since it aimed to present a conceptual model for a possible routing algorithm. The remainder four articles [38-41] report the use of simulation to verify the validity of the proposed algorithms. Moreover, three of these articles [38,39,41] report the use or real-life data: the map of the City of Ottawa [41], possible routes between different pairs of source and destination from the City of Barcelona [38], and from the City of Warsaw [39].

In terms of the development of applications, considering the validation methods, it is important distinguish the different development phases, each one with a different maturity level. For that, the systems' development life cycle should be considered, which includes various phases (e.g., requirements, analysis, design and implementation, testing, and evolution or maintenance). Moreover, when developing applications for end users, a user-centered design process [57] is considered more effective. This means, that the type of involvement of end users should be considered when defining the methods to be used in the different phases.

Most of the included studies aiming to develop mobility assistants are still in an early development phase (i.e., description of concepts or architectures): three articles report concepts for further development [42,50,52] and other three described the architecture that were implemented [46,47,49]. Moreover, two articles [48,51] reported the test of prototypes in real-life scenarios. The remainder articles report proof-of concepts prototypes [43-45,53-55].

In article [43], the proposed application is compared with commercially available route planning applications, considering (i) the accuracy of expected total travel time, (ii) the ability to dynamically rank candidate routes dependent on departure times, and (iii) the ability to consider the reliability of paths. The comparison was performed in Singapore. Also in Singapore, [45] compared the effectiveness of the proposed solution with two popular journey planners. In [44] an experiment was conducted to determine the success level of the reported solution when determining routes for the City of Rome.

Furthermore, in [53] is reported an evaluation of different configurations of services designed for travelers going towards high traffic areas, while in [54] an experiment was conducted to evaluate the accuracy of the proposed solution. Finally, in [55], information from the City of Pamplona, Spain, was used to assess the adequacy of the architecture that was implemented.

The articles reporting prototypes tested in real-life scenarios [48,51], considered the assessment of the user experience together with other features.

According to [51], the authors conducted an evaluation process of the mobility assistant focused on usability, accessibility, ease of use, robustness as well as functionality. For that a questionnaire prepared by the authors was requested to be filled in by the 71 test users and the mobility assistant was on average assessed positively [51].

Moreover, [48] reports the integration of the mobility assistant into the municipal bus infrastructure in Madrid, Spain, since 2013. It is available to the public

as a free smartphone application that was downloaded by 750 users since it was first released. The mobility assistant was improved over two consecutive user trials aiming a technical test of the system effectiveness and the assessment of the user experience [48]: (i) the first study was devised to collect quantitative feedback from a broad set of users of the mobility assistant by integrating a short questionnaire prepared by the authors into the application; and (ii) the goal of the second study involving ten participants was to analyze the attitudes and feelings that the participants developed during the use of the application. Several participants expressed positive experiences about improved information accessibility [48].

4. Discussion and Conclusion

Considering the current trends of research related to mobility assistants to support multi-modal routes in smart cities (i.e., the first research question), five of the retrieved articles report algorithms to determine optimal multimodal routes, while the remainder 14 articles report the development of mobility assistants.

In terms of algorithms, although the general goals are the same, the studies present different specific aims and, consequently, various approaches are envisaged: (i) in article [40] the global multimodal network is abstracted into sub-graphs related to either a particular mode of transport or the road traffic network of the city; (ii) article [37] proposes a method for planning routes considering both the distance from origin to the destination and the passengers' density of public transports; (iii) article [38] proposes a method to provide tourists with safe and efficient itineraries considering mobility policies; (iv) article [39] aims to maximize the number of bike stations that are balanced and to optimize the route planning process; and (v) article [41] presents an optimization model to determine the best routes for the passengers based on the game theory.

In what concerns the articles reporting the development of mobility assistants, a general concern is to aggregate heterogeneous sources of data to provide the users with optimal routes considering not only the distance between the origin and the destination but also other parameters such as the availability of alternative transport modes [51] or the crowd density of public transports [48].

According to Table II, in addition to static data sources (e.g., public transportation schedule data [42-55], digital maps of the roads network [42,45,47,49,53,55], existing parks in the city [42,47,49,52,53,55] or existing shared transport means [43,51-53,55]), the mobility assistants use dynamic data sources: (i) real-time road traffic [42,45,52,53,55]; (ii) real-time public transportation data [42-46,48-50,52,55]; (iii) shared means data [42,49,51,55]; (iv) weather data [42,45,52,55]; (v) air pollution [52,55]; (vi) noise pollution [55]; (vii) crowd data from social networks [42,47,54,55]; (viii) data related to city policies and regulations [47]; and (ix) touristic features data [52].

There are considerable differences in terms of the types of data that are considered to support the proposed approaches for the mobility assistants. For instance, among the articles reporting the usage of real-time traffic data, they considered different sources: (i) vehicle data from bus, trains, cars or bikes and data from other information systems [42]; (ii) probing vehicles which roam the city and report their location and speed in real-time and other information systems [45]; (iii) traffic sensors [42,53,55]; and (iv) other information systems [55]. Therefore, it is possible to conclude that although the included studies have similar goals, the data types being used are quite different.

Regarding the methods that were used to assess the solutions being reported (i.e., the third research question), it should be mentioned that most of the articles report prototypes that were developed to demonstrate the feasibility of the concepts. Indeed, only two articles report prototypes that were assessed by real users [48,51].

Moreover, looking in detail for the assessments being performed, there is a lack of robust methodological approaches since ad-hoc questionnaires were used to assess usability, the design of the studies and the measured outcomes were poorly described and, in general, the number of participants was small.

Therefore, in terms of the major barriers for the dissemination of the applications being reported (i.e., the fourth research question), a major drawback is the lack of robust evidence to facilitate the dissemination process. Although technologies should respond to the individuals' needs and not the other way around, within this set of included articles, there seems to be scarce concern in verifying the effectiveness of the solutions designed to fit the individuals' perspectives.

The key objective of this research study was to identify the current research trends related to mobility assistants using in smart cities' infrastructures to support multi-modal transportation situations. To accomplish this objective, a scoping review of the literature was conducted. After this revision, it is possible to state that although relevant arguments were made regarding the importance of mobility assistants supported in smart cities' infrastructures, the total number of studies that satisfy the inclusion and exclusion criteria is not very representative within the total of studies related to smart cities. Moreover, the included articles do not represent relevant added value in terms of translation from research to concrete solutions with impact in daily living of the citizens.

It is always possible to point out limitations about both the chosen keywords and the databases that were used in this study. Moreover, it should be borne in mind that there are many conferences not indexed in Web of Science or Scopus databases, which means that, certainly, there are similar articles that have not been included in this scoping review. However, this study followed a rigorous method, which means that it might contribute with valuable information to optimize future smart cities' developments.

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Risk management in the healthcare safety management system

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Abstract. The paper discusses the main components of the modern system of risk management in medicine. Using the ISO 31000 standard of risk management and the ARIS integrated modeling environment, the authors have built a model of the risk management process in a medical organization, including the accounting subsystem, the risk analysis subsystem, and the risk processing subsystem. The concept of risk management proposed in the article is formulated on the basis of a system safety model, which assumes that adverse events related to the provision of medical care are based on systemic causes that under certain conditions turn into a hazard, and the latter is used to receive active threats and incidents. The risk management system is an executive block of the safety management system in a medical organization, which includes (in addition to risk management) an ideological block (a new safety culture) and an educational block (an organizational learning subsystem).

Keywords: health care security, risk management, latent threats, hazards, active threats, incidents.

1. Introduction

Studies in recent years have convincingly demonstrated that health care is not a safe service area. Thus, in the provision of medical care, one in five patients faces a medical mistake. One in eight hospitalized patients becomes a victim of additional harm associated with the provision of medical care. One in eighty inpatients receives severe harm or becomes disabled. One in 160 hospitalized patients dies from complications related to the provision of medical care. Adverse events cause every fourth inpatient death and every tenth death in a population of developed countries [1,2].

Due to the much earlier focus on safety, many other high-risk industries have made much more progress in this regard. Thus, for example, civil aviation is 30 thousand times safer than stationary healthcare. It was possible to reach such significant results in less than 40 years thanks to the construction of a safety management system in high-risk enterprises. Similar systems for managing the safety of medical care have already been implemented in the best medical organizations of the world, which justly serve as the benchmark in terms of generating new knowledge and scaling effective solutions [3-8]. The health care safety management system includes three blocks (Fig. 1): the ideological block (new safety culture), the executive block (risk management system), and the educational block (organizational learning subsystem).

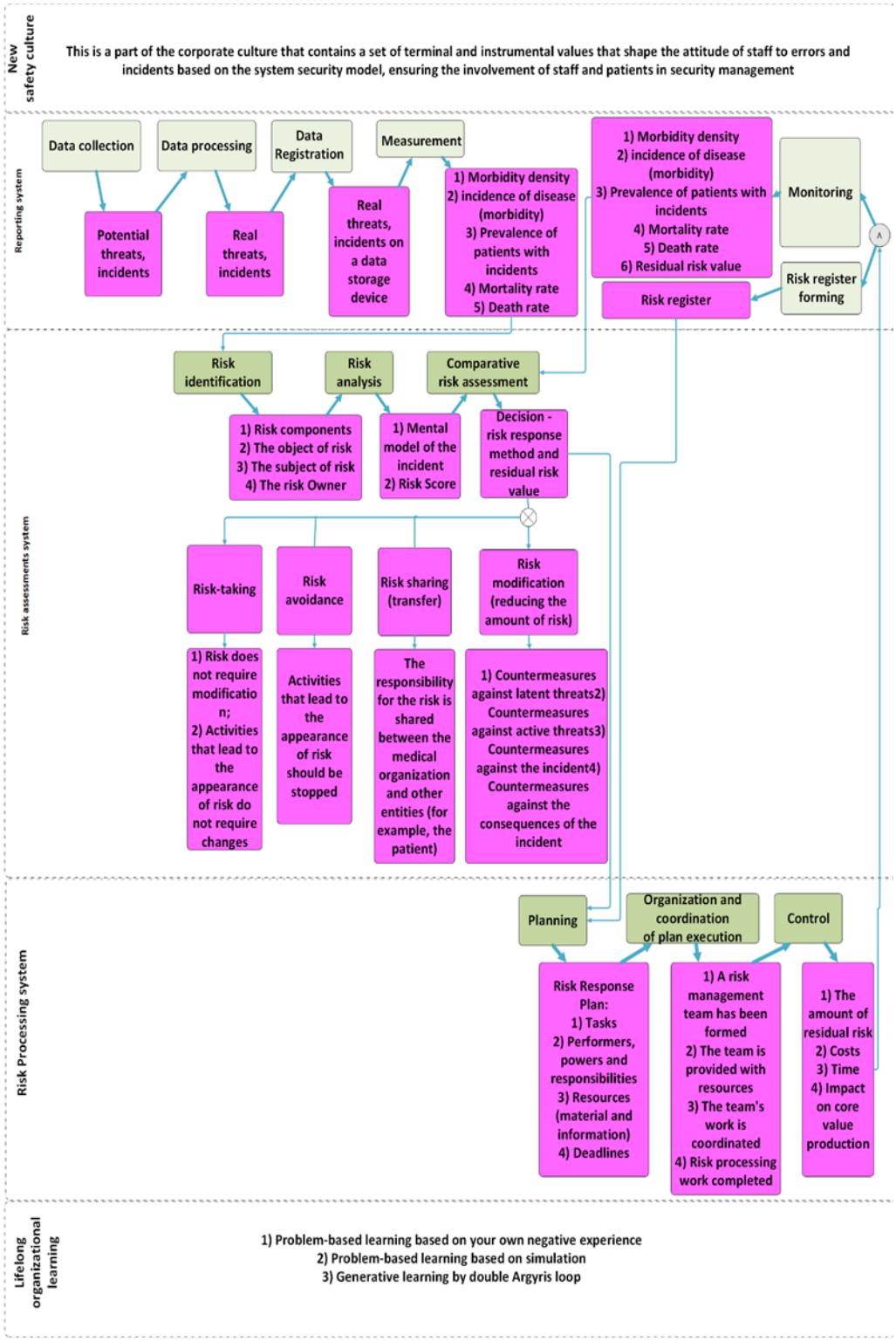


Fig. 1. Healthcare safety management system

The risk management block includes three subsystems: the accounting subsystem, the risk assessment subsystem, and the risk processing subsystem. The accounting subsystem implements five main functions: data and information collection, processing, registration, measurement, and monitoring of data and information (Fig. 1). The modern accounting subsystem, in addition to incidents and their consequences, registers the previously described latent and active threats [1, 2, 9-13,15-17].

The interconnectedness and interdependence of the described components determine the particular importance of their coordination in both inpatient and outpatient health care. Coordination of the main subsystems of the executive unit, namely, accounting subsystems, risk assessment subsystems, and risk processing subsystems, is of particular importance. The modeling of the risk management system as a complex process of managing systemic root causes and active threats is of great importance in improving the efficiency of work [9-13].

2. Data and Methodology

The paper is an analytical study on the problem of risk management in healthcare. The purpose of the work was to build a risk management model based on a system safety model that can later be formalized in the management activities of a medical organization. The search for information was conducted by three researchers independently over the period 1980-2020 using MEDLINE medical databases, Cochrane Collaboration; EMBASE, SCOPUS, ISI Web of Science. Retrospective observational studies of high methodological quality, analytical collections, and original scientific articles were used.

The authors built a system model of safety using the technology of simulation modeling in the form of agent-based modeling. To describe the actions and events of the authors, the authors modified the EPC notation of the integrated modeling environment ARIS with the following elements: start event (starts the process) - a rectangle with red fill; end event (process result) - a rectangle with purple fill; intermediate event (an intermediate result that makes sense) - a rectangle with pink fill; action-rectangle with green fill; control flow arrows (indicate the direction of the action and connect the action to the intermediate or final event) - blue arrows; arrows of the information flow (connect the starting action with the subsequent action) - red arrows; ^ - logical operator "AND"⊗ - logical operator "EXCLUSIVE OR". The risk management process was modeled using the modified BPMN notation for the ARIS modeling environment [14].

3. Results

Being dependent on new safety culture and a culture of high reliability, modern risk management in healthcare is based on a system safety model that describes the mechanism for the development of an incident and its consequences, taking into account the constant systemic root causes. A key paradigm is that any incident is based on a relatively constant set of root causes or directive latent threats. Under the influence of triggers or starting events, the root causes are initialized and they turn into a hazard, which is then used to receive active threats, and the latter to receive an incident. Another group of latent threats, called contextual threats, when exposed to a trigger or start events, turns into vulnerabilities that level the protection system on the way to transforming a directive latent threat into an incident (Fig. 2).

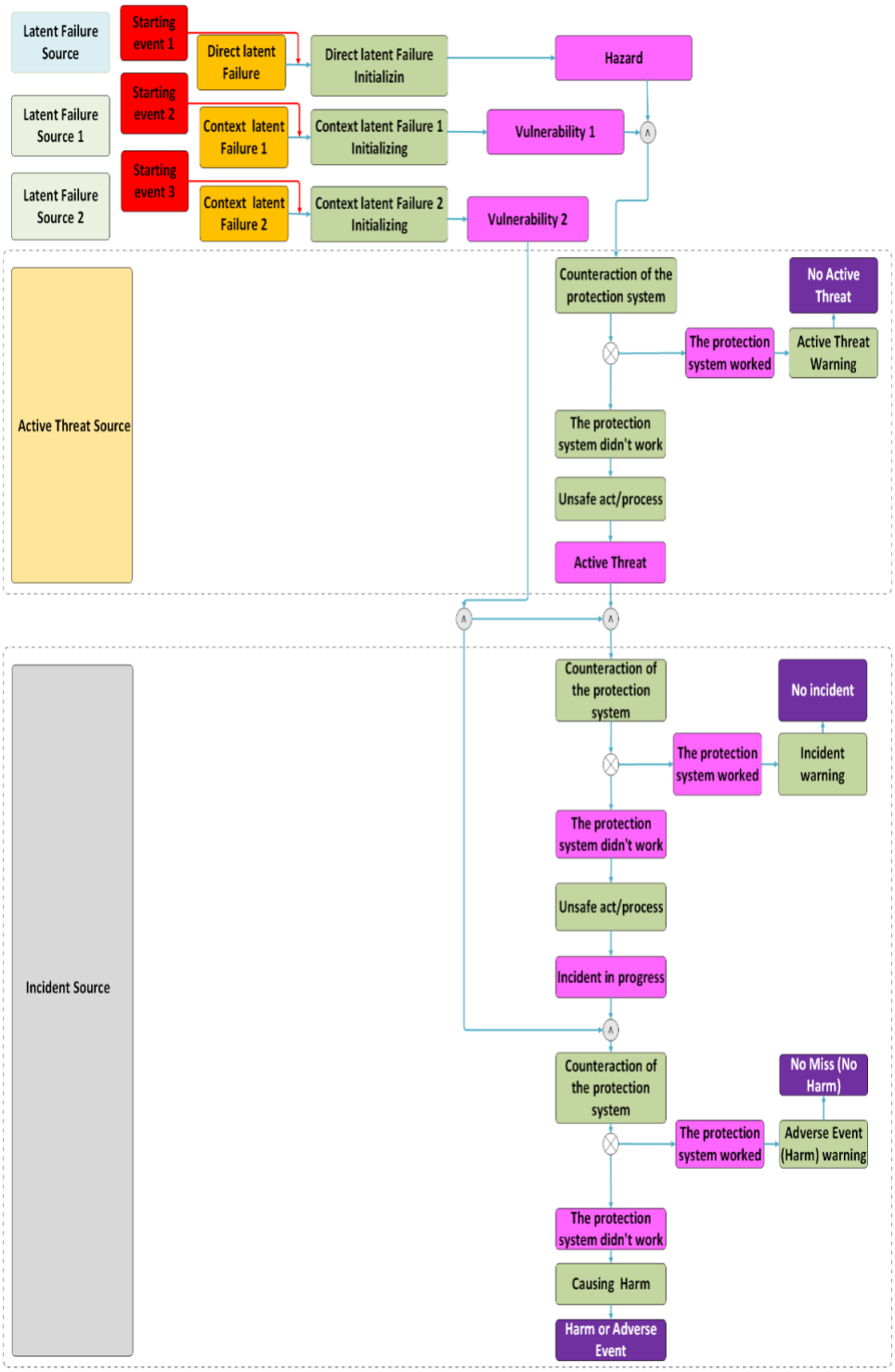


Fig.2. The development of an incident and its consequences

Latent threats are generated by sources of latent threats, which may be medical technologies, the organization's staff, the production environment, and the patient himself. Active threats (staff mistakes and violations, unsafe processes in the environment, and patient mistakes) and incidents also have their own sources. As a general rule, the level of the source of latent threats does not coincide with the level of the source of active threats and the incident. For example, a latent threat of matching personal data of patients, the source of which is the patients, is subsequently transformed into an identification error – an active threat and an incident associated with it (an intervention performed on the "wrong" patient), the sources of which are the organization's staff [1, 2, 15-17].

In order to unify the registration process, most countries of the world use the letter coding of threats and incidents [18, 19], proposed by the US National Coordinating Council on Medical Errors (Table 1).

Table 1. Coding of failures, threats, and incidents

Code	Event type	Comments
A	Latent failure and vulnerability	Circumstances or events that have the capacity to cause an error
B	Active threat	An error that did not reach the patient
C	Incident without harm (near miss)	An error that reached the patient but did not cause harm
D	Incident without harm (near miss)	An error that reached the patient and required monitoring or diagnostic procedure to confirm that it resulted in no harm to the patient
E	Harm (accident or adverse event)	Temporary dysfunction that required intervention without increasing the duration of inpatient treatment
F	Harm (accident or adverse event)	Temporary dysfunction that required intervention and initial or prolonged hospitalization
G	Harm (accident or adverse event)	Permanent function impairment (disability)
H	Harm (accident or adverse event)	Life-threatening disorders that required intervention to sustain life (cardiopulmonary resuscitation, intensive care, and/or major interventions)
I	Critical incident	Patient death

Most of the problems in risk management arise in the accounting subsystem. At the collection stage, the main problem is the poor quality of data and information. At the stage of information processing, the main problem is masking, when the connection of the complication with the provision of medical care is ignored. At the registration stage, when the described link cannot be ignored (for example, an infection associated with the provision of medical care), another problem is concealment, when the identified complications are simply not recorded. The main problem at the measurement and monitoring stage is pseudo-optimization when the measurement includes only those data that are beneficial to the organization or to its responsible persons [1, 2, 15-17].

Effective solutions are proposed to prevent the described problems. Thus, at the stage of collecting information, it is necessary to determine the data source. There are two groups of data sources: those with high and low dependence on the subjective factor. The first group of sources provides more representative information but also is subject to the greatest distortion. Therefore, the emphasis on it can be made only after the full establishment of a new safety culture in the organization (Table 2) [1, 2, 15-17].

To prevent masking, it is necessary to standardize the identification and verification of incidents. To prevent concealment, important actions can include the creation of an innocent climate within the framework of a new safety culture,

incentives for recording incidents, as well as the use of the methodology of global instrumental triggers. To prevent pseudo-optimization, a balanced assessment of the indicators obtained during the measurement is required, taking into account the ratio of incidents of varying severity, the analysis of incidents in various departments, and the ratio of incidents with fatal outcomes [20-26].

The risk assessment subsystem performs the functions of risk identification, assessment, and comparative analysis. Risk identification consists of identifying the latent and active threats, hazards, vulnerabilities, and incidents described above, as well as the object, subject, and owner of the risk. Risk assessment includes incident analysis and risk assessment [11-13].

Table 2. Sources of Data and Information

With high dependency on a care provider		**With low dependency on care providers**	
Source	Method of obtaining data and information	Source	Method of obtaining data and information
Personnel	Voluntary communication Voluntary reporting	Auditor	Direct control of staff actions and medical records Analysis of ratio incidents of various severity
Medical records	Retrospective analysis Prospective analysis	Patient	Interview with family Complaints from patients and their families
Colleague	Cross-Control	Automated control systems	Automation of error accounting Automation of complaint recording
Official (mandatory) reporting	Analysis of integral indicators (lethality, complications, etc.)	Official (mandatory) reporting	Cross-analysis of integral indicators dynamics (mortality and complications dynamics)
		Global Trigger Tool	Atypical event analysis Atypical death analysis Atypical complications analysis Atypical patient behavior analysis

Incident analysis or root cause analysis involves determining the entire chain of transformations from latent threats to the incident. The incident analysis involves the identification of sharp, intermediate, and blunt edges in the process of providing medical care. At the sharp edge, we have the patient, the sources of directive latent threats, active threats, and the incident. The blunt edge is not directly related to the patient and contains sources of contextual latent threats. The vector of incident analysis is always directed from the sharp edge to the blunt edge. At the sharp edge, it is necessary to evaluate the isolated influence of each factor, as well as the influence of the interface in the form of their technological interaction. In order to analyze the root causes and identify their sources, it is quite effective to use the Ishikawa causal diagram with simultaneous analysis of all possible sources of latent threats. Moving along branches, we end up with a permanent directive or contextual root cause. The logical conclusion of the incident analysis is the mental model of the incident, which shows the entire chain of transformations from the directive latent threat to the incident and its consequences. Fig.3 shows the mental model of an incident, namely, performing an intervention on the wrong organ. Thus, Fig. 3 demonstrates the entire chain of transformation from a directive latent threat to an incident [1, 2, 15-17, 27-29].

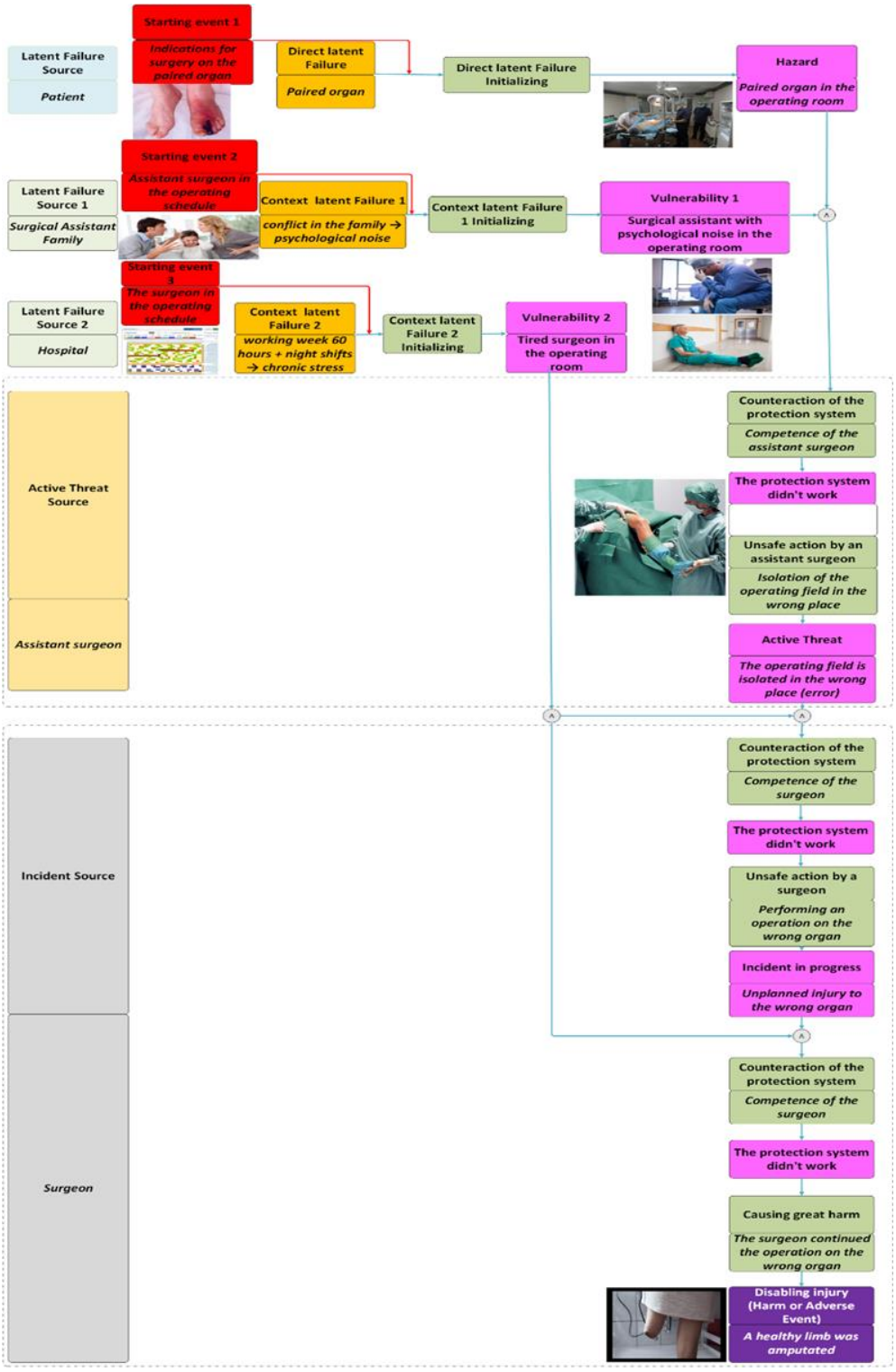


Fig.3. The mental model of an incident

To assess the magnitude of the risk, it is necessary to obtain information about the nature and severity of the risk event, as well as its frequency characteristics. Risk events include incidents without consequences and incidents with consequences. To determine the amount of risk, it is necessary to bring the frequency and quality characteristics of risk events to a single scale. These requirements are best met by the rank scales. The most popular of these is the scale proposed by the British National Health System. The severity of the consequences of the incident is calculated according to the criteria listed in Table 3.

Table 3. Incident's stratification according to the severity of harm*

Score	Name	Severity of harm (scale equivalent NCC MERP)	Number of personnel involved	Additional treatment period	Additional treatment costs (pound sterling)
5	Catastrophic (critical)	I	> 50	-	> 1 million
4	Major	G, H	16-50	>15 days in the hospital	500 thousand - 1 million
3	Moderate	F	3-15	8-15 days in the hospital and 1-7 days outpatient	250 -500 thousand
2	Minor	E	1-2	1-7 days in the hospital and 1-7 days outpatient	10-25 thousand
1	Insignificant	C, D	0-1	not required	< 10 thousand
*NHS Foundation Trust. Risk Management Procedure. January 2013					

The estimation of frequency characteristics will depend on the presence or absence of statistical history. If there are incident statistics, the repeatability indicator is used, and if there are no statistics, the expert probability assessment is used (Table 4).

Table 4. Stratification of incidents based on frequency and probability

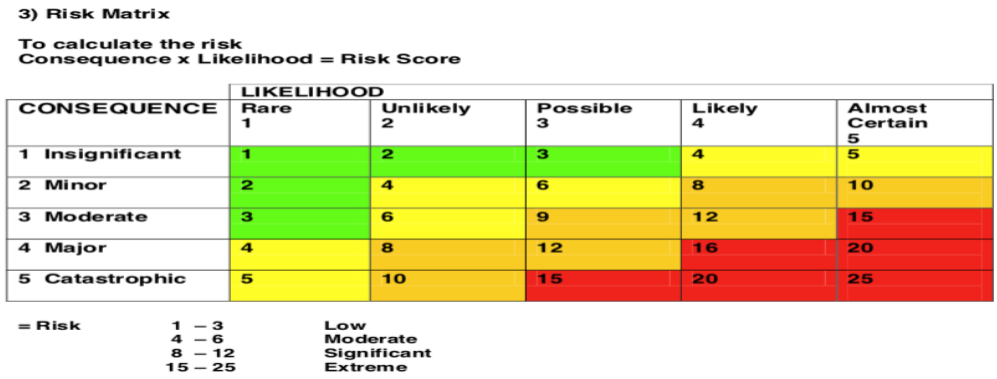
Score	Development probability	Statistic	No Statistic
		Frequency of occurrence 1 case	Incident probability over a period
5	Almost certain	1 time a week or more	0,81-1,00
4	Likely	1 time in 8-30 days	0,61-0,80
3	Possible	1 time in 31-60 days	0,41-0,60
2	Unlikely	1 time in 61 days – 12 months	0,21-0,40
1	Rare	Not if there are latent threats	0,20 and less

Multiplying the two rank values allows you to get the value of the risk, which in the thermal risk matrix can be attributed to one of the four zones: low risk, moderate risk, high or catastrophic risk (Fig. 4).

Comparative risk analysis involves comparing the amount of risk with the risk criteria and choosing the method of responding to the risk. A medical organization uses three criteria: acceptable risk (the amount of risk that the organization is willing to accept without modifying it), acceptable risk (the amount of risk that the

organization is willing to accept after modification), and preferred risk (the amount of risk that the organization seeks to achieve) [9-13].

Taking into account the described criteria, 4 key risk response methods are used in healthcare: risk acceptance, risk avoidance, risk sharing, and risk modification. In this case, several methods can be used simultaneously, for example, risk modification and risk-sharing (informed consent of the patient). Risk acceptance is allowed if the risk value is classified as an acceptable risk. Risk avoidance consists of stopping the activity that leads to the occurrence of a risk event. Risk-sharing involves sharing the responsibility for risk between the medical organization and other persons (for example, the patient) [1, 2, 9-13,15-17].


3) Risk Matrix

To calculate the risk
Consequence x Likelihood = Risk Score

	LIKELIHOOD				
CONSEQUENCE	Rare 1	Unlikely 2	Possible 3	Likely 4	Almost Certain 5
1 Insignificant	1	2	3	4	5
2 Minor	2	4	6	8	10
3 Moderate	3	6	9	12	15
4 Major	4	8	12	16	20
5 Catastrophic	5	10	15	20	25

= Risk

1 – 3	Low
4 – 6	Moderate
8 – 12	Significant
15 – 25	Extreme

Fig. 4. Thermal risk scale (NHS Foundation Trust. Risk Management Procedure. January 2013)

Table 5 demonstrates different ways to respond to the risk, taking into account its initial value. These ways involve not only the methods of response but also the attitude to medical care, the area of risk management, and the frequency of monitoring. Risk modification consists of reducing the amount of risk to an acceptable level.

Table 5. Risk Response Plan for different sizes

Risk value	Medical care	Risk management area	Monitoring	Risk response
Low	continues	Risk owner	every six months	Accepted and sharing
Moderate	continues	Risk owner	quarterly	Modification and sharing
Significant	continues	- risk owner - other departments -organiz ation management	monthly (if they score 10 or more); bi-monthly (if they score below 10)	Modification and sharing
Extreme	continues	- risk owner - other departments - organizational management - health care authority	monthly	Avoided or Modification

There are three main methods of risk modification: eliminating risk sources (countermeasures against directive latent threats), reducing the probability of a risk

event (countermeasures against contextual latent threats and active threats), and reducing the severity of the consequences of a risk event (countermeasures against incidents). In the case of risk modification, organizations of high reliability try to provide countermeasures at all levels of turning a directive latent threat into an incident (Fig.5) [1,2, 9-13,15-17].

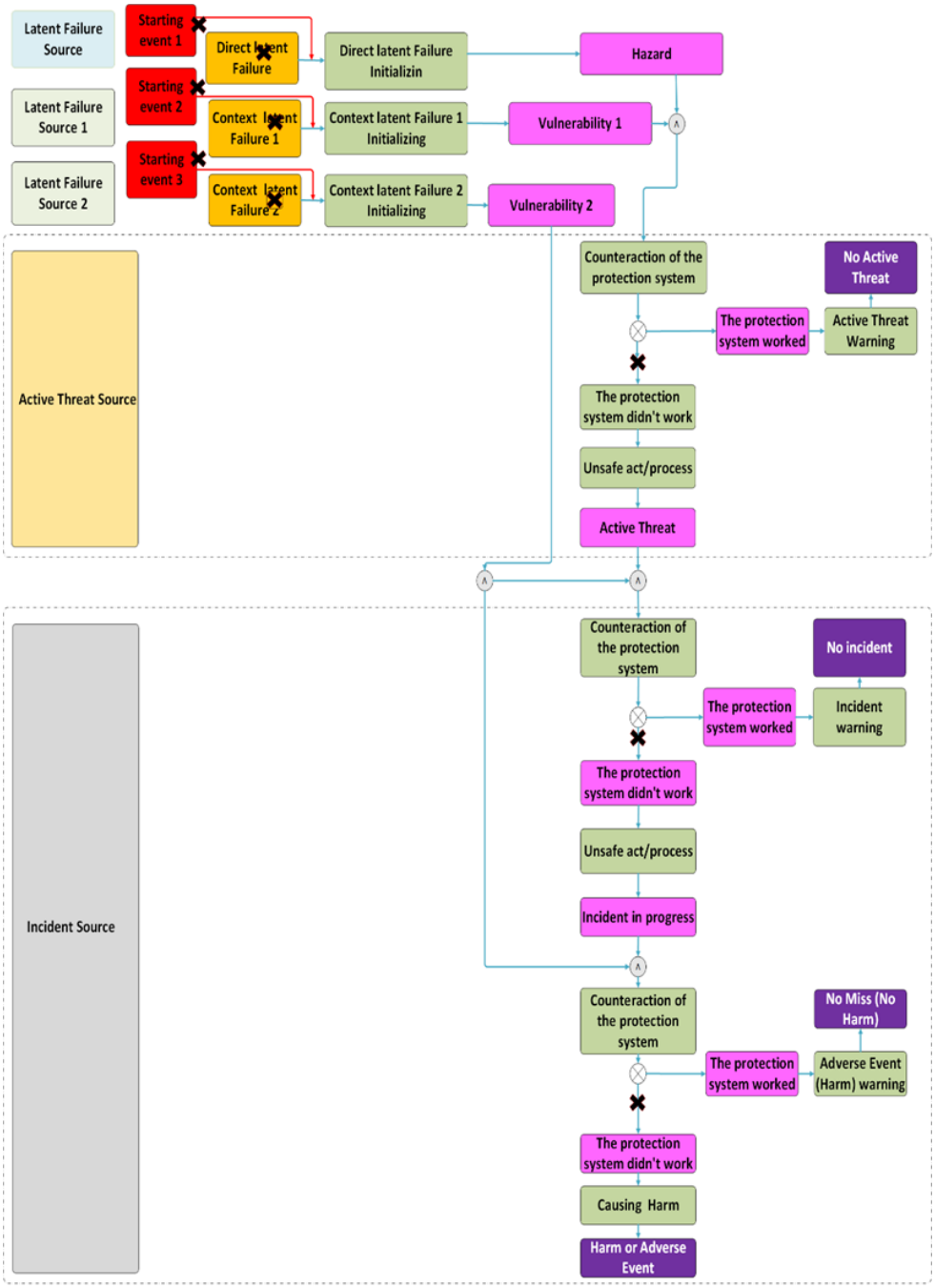


Fig.5. Countermeasures against transformation of a direct latent threat into an incident

The risk management subsystem includes a risk response plan, organization, and coordination of plan execution, as well as the monitoring of the effectiveness of measures. The plan itself is a detailed description of the decisions made concerning the tasks, resources, deadlines, and performers (Table 6) [1, 2, 9-13, 15-17, 30-31].

Table 6. Risk response plan

Medical care provided by the risk owner	Response method	Risk management area	Resources for risk manage-ment	Residual risk level
continues ends	risk accepted risk minimized risk eliminated risk is avoided	risk owner other departments medical organization health care authority	people finance material inventories info	Risk value determined by the risk management committee in a medical organization

Monitoring the effectiveness of measures consists primarily in assessing the immediate results in the form of the amount of residual risk, time and resources spent, the impact on the production of the main value, as well as in the subsequent monitoring of the prevalence, incident, and incident density. Measures that have proven their effectiveness, together with the risk description, should be standardized and formalized in the risk register. The best solutions for common risks need to be scaled in other parts of the organization. The frequency of monitoring is usually determined by the initial amount of risk, and subsequently by the amount of residual risk. In addition, new risks associated with the introduction of new technologies, the use of new medicines and medical devices, the hiring of new employees, and changes in legislation should also be monitored [1, 2, 9-13, 15-17, 32-33].

4. Conclusion

The described risk management methodology, based on the system safety model, can be successfully replicated in any type of medical organization. At the same time, many elements of the model (for example, the accounting subsystem) can be automated, what will significantly increase the efficiency of the healthcare safety management system due to a significant reduction in the influence of the human factor on the management outcomes.

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Integrating a New Generation of Interoperability Agents into the AIDA Platform

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Abstract. Health is an information rich and complex environment, which makes it essential to implement interoperability in different health organizations and the consequent homogeneity among Health Information Systems (HIS). The Agency for the Integration, Dissemination and Archiving of Medical and Clinical Information (AIDA) is a consistent agent monitoring platform capable of guaranteeing the automation of information as well as the interoperability and integration of HIS. This platform was designed as a solution to the information islands that are commonly found in hospital systems, and it is currently being used in several hospitals throughout Portugal. However, like any technological innovation, the solution requires a constant health technology assessment (HTA) to ensure the absence of obsolescence and a continued efficiency and security of the platform. Hence, this article focuses on the relevance and the need for vigilance, culminating in the restructuring of certain intelligent agents that make up the AIDA platform.

Keywords: Health Information Systems, Interoperability, Obsolescence, Health Technology Assessment.

1. Introduction

In recent times, technological and scientific advances in the field of information have been presented as the main drivers for creating a new era world. The "Information Age" appeared after the "Industrial Age" and accompanies us until today, with continuous growth and valorization of information and technology as well as significant improvements in society's quality of life [1].

Nowadays, with a society that increasingly privileges information, coupled with the growing amount of data produced internally and externally by organizations, it is crucial to accelerate the implementation of Information Systems (IS), capable of responding to problems related to the flow of information [2]. Through these systems, the development and growth of an organization in a market without borders is guaranteed since they enable the storage and manipulation of vital information for decision making [3] [4]. Therefore, for a competitive and profitable advantage, the application of Information Technology (IT) is fundamental, since it covers the set of all solutions and human and/or computational resources that allow access, consultation, management and use of information [5] [6].

In the information society, the binomial IS/IT is used in the most diverse areas and activities of daily life, including the health area. In consequence, the Medical Informatics (MI) emerges with a leadership role in the search and evolution of innovative solutions, capable of guaranteeing quality in decision support and in clinical practice.

Health is a complex environment that is enriched with information from different sources and that needs to be accessed by multiple health professionals at any time and in distinct locations [7]. In this sense, it is through Health Information Systems (HIS) that it is possible to aggregate and process all data and information from the health environment, which, consequently, contribute to the decision-making process and guide the entire process of managing the institution's clinical and administrative information [8]. With the applicability of these information systems, it is possible to guarantee the progress and optimization of clinical processes, quality in the provision of health care, the reduction of costs and clinical errors as well as the increased satisfaction of health professionals and patients [9].

Nevertheless, HIS are usually characterized as complex and consisting of distributed and heterogeneous systems, whose interaction between them and accessibility to them in a timely manner is nowadays fundamental to the success of clinical processes [10][11]. So, it becomes essential to rely on interoperability and its integration at different conceptual levels in order to use HIS capable of cooperating and communicating with each other ensuring, in this way, the sharing and communication of information between all units and health professionals in their hospitals [12].

AIDA is an example of these complex systems, whose main objective is to integrate, disseminate and archive large sets of information from different sources, such as services, departments, units, computers and medical devices, assist medical applications and control the flow of information through a network of intelligent information processing systems with an adjustable level of autonomy [12] [13] [14]. This platform consists of several agents it is important to highlight agent 61 and agent 62, which are responsible for interacting with hospital partners through the exchange of Health Level Seven (HL7) messages. Agent 62 ensures the creation and sending of HL7 messages from AIDA to various partners, whereas agent 61 is responsible for receiving, interpreting, and processing the HL7 messages sent by hospital's partners. The AIDA platform is currently in use in several hospitals across Portugal, including the Centro Hospitalar Universitário do Porto (CHUP), which will serve as the case study for this article.

As the exchange of information between hospital partners and their interpretation are fundamental aspects of hospital operation, it is essential to seek to maximize their performance while reducing the occurrence of errors and inconsistencies. In this sense, the focus of this study is to ensure a successful and efficient communication between the AIDA platform and all the third-party companies involved in the provision of health care within the CHUP. To achieve this goal, the intelligent agents 61 and 62 of AIDA will be carefully assessed and reformulated according to the hospital's needs.

The present paper is organized into five sections. After the Introduction, we provide a Background to contextualize the readers in the topic addressed in this paper with particular emphasis on the concept of Interoperability and the AIDA platform. Subsequently, in section 3, the importance and value of the reformulation of technologies implemented in CHUP hospital units is explained, in order to solve problems of obsolescence and redundancy. Focusing on the impact of the reformulation of agents 61 and 62, responsible for the exchange of information between the different systems of the AIDA platform. Finally, the results achieved with this measure and the main conclusions are presented, as well as some perspectives for future work.

2. Literature Review

2.1. Interoperability

Despite being a term often used today, the meaning of interoperability remains ambiguous and diffuse. In this sense, and in general terms, it is possible to integrate the various definitions found in the scientific literature and characterize the concept

of interoperability as the ability of different systems to communicate and exchange information with each other, and to process and interpret this information correctly [15].

For health, the implementation of interoperability in different health organizations and the consequent homogeneity among HIS guarantees a diversity of benefits. In fact, with the implementation of interoperable IS in the health area, better care and provision of health care is guaranteed and, consequently, a reduction in medical errors, since health professionals have a better access to a range of relevant and reliable information when and where they need [16].

However, the integration of interoperability in a hospital environment proves to be a challenging task, since it is crucial that all information transferred is standardized to avoid different structures and misunderstandings. In this way, for interoperability between HIS, it is essential to use different standards to ensure the normalization of information. These standards can be divided into three distinct purposes: referring to the representation of clinical information (SNOMED-CT), to communication (HL7) and, finally, to the medical image block (DICOM) [12] [17].

Among all these, the HL7 protocol is perhaps the most internationally recognized and defines a set of standard formats that, through a message structure, allows the exchange of information between different heterogeneous hospital applications [5]. Initially, the versions of HL7 were exclusively syntactic, however, nowadays, the most current version (version 3), in addition to defining a syntax for the messages exchanged, seeks to incorporate semantic interoperability, including the appropriate use of information exchanged in the direction of the communication behavior of applications [18].

Although interoperability between systems prove to be a common interest and comprehensive within the scientific community, however, is a complex method that, these days, has not yet achieved a consensus definition and implementation [5].

2.2. AIDA

In order to keep up with technological advances in different hospitals, reduce medical errors and, consequently, improve health care, it is essential to implement a consistent platform agents monitoring able to ensure the automation of information and interoperability and integration of HIS. In this regard, the Artificial Intelligence Group, Department of Informatics, University of Minho, dedicated to the construction of an intelligent and dynamic platform, in partnership with the Centro Hospitalar do Porto (CHUP), with the aim of making interoperable HIS, the AIDA.

The AIDA platform is a complex system that consists of specialized and direct intelligent agents, in charge of tasks such as communication between its various subsystems, sending and receiving information, as well as managing and storing information and responding appropriately to user requests. This system uses several means of integration, including technologies such as Service Oriented Architectures (SOA) and Multi Agent Systems (MAS) to ensure interoperability between hospital subsystems, assuming a central role where it is installed [11, 17, 19].

The success and functioning of AIDA is essential since it is a platform associated with the health area, where a simple mistake can have serious consequences for the health organization and, indirectly, to the health status of different patients.

For this reason, it is essential to guarantee the cooperation between the various intelligent agents and their individual maintenance.

3. Data and Methodology

The development of the present study was based on the Design Science Research (DSR) methodology, which is used in the construction and evaluation of useful and rigorous IT solutions.

DSR is a rigorous process methodology at the level of scientific research and that allows, through the projection of artifacts, professionals to solve observed problems and process information. These resulting artefacts should be viable solutions capable of resolving, in an excellent way, the objectives initially proposed and the problem in question [20, 21, 22].

The model of the DSR methodology, is represented in Figure 1. In a first phase, this methodology identifies the problem and the motivation, as well as defines the objectives of the solution. Then, the artefact is designed and developed, in a rigorous scientific process based on the knowledge and theory previously explored, which implies an initial research that is as enlightening and efficient as possible. In a next step, the solution should be applied to a specific case and, subsequently, evaluated with relevant metrics if the defined objectives have been achieved. Finally, if the assessment is conclusive, the artifact must be communicated to the relevant entities. If the results are not conclusive, the stage of setting objectives is returned, or a new projection of the artifact is carried out [23] [24].

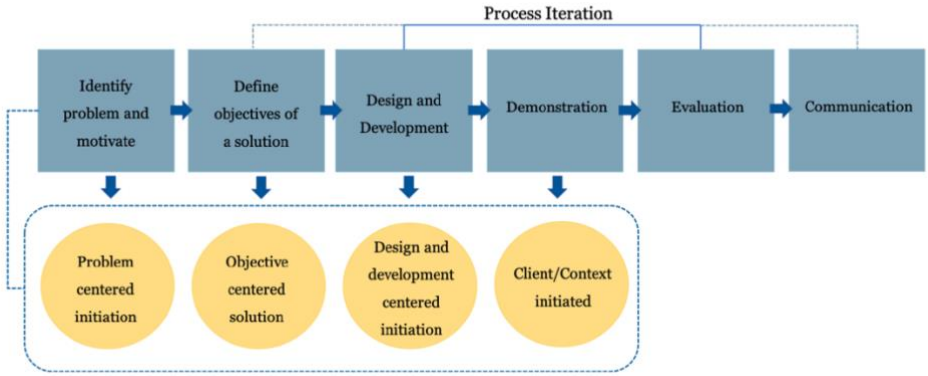

Fig. 2. Model of the DSR Methodology. Adapted from [22, 23].

In the present paper, the case study developed follows the DSR methodology, since, after an analysis of the current state of the technologies implemented in the CHUP hospital units, the presence of obsolescence was detected in certain intelligent agents that make up the AIDA platform.

Following the identification of the problem and resulting motivations (mentioned in the Introduction and earlier in this section), it was proceeded to the definition of the objectives such as the assurance of interoperability and integration between the different systems. After a concrete definition of the problem and objectives, it was possible to restructure these agents and, finally, in a conclusion phase, highlight the added value of the work.

3.1 Problem Identification

Given the constant technological and scientific progress, IS developed and their applications may become obsolete and without the capacity to respond to the needs of an organization. In the IT area, obsolescence is defined as a component or system (hardware or software) that is no longer viable, useful or capable of performing the necessary functions, despite being in perfect working condition [25] [26]. Nowadays, and due to the exponential technological development, the presence of obsolescence in any organization is a frequent concern, especially in organizations such as health institutions.

With the informatization of health care systems comes an increasing risk of technological obsolescence. As health care systems increasingly rely on technology,

the risk of technological obsolescence grows. Despite its significance, its resolution is not always seen as a priority, as it is widely acknowledged that the hospital system is one of the most complex, with a wide range of demands but limited resources. In this regard, hospital administrations are often forced to comply with a tight budget that prioritizes the acquisition of hospital physical resources such as beds, monitors, ventilators, computed tomography (CT) scanners and cutting-edge equipment, as well as innovative medication and treatments. The few remaining financial resources are usually spent on acquiring new software, leaving the maintenance, and updating of already implemented technological solutions to the sidelines.

Despite not being included in the budget as a priority, technological obsolescence is in fact impacting in these institutions. Their presence may affect the minimization of costs and resources and negatively affect the provision of health care and, consequently, the patient's health.

In this sense, the systematic existence of a HTA is essential, through which the system or component is evaluated using different parameters, such as performance, reliability, environmental impact, and cost. The presence of these assessments ensures that the technology remains safe and effective, that the cost-benefit ratio is superior to the integration of an alternative, the provision of health care, and, as a result, the patient's health status [27].

By carefully performing an HTA on different systems, platforms, applications and others present in units of the CHUP, it was identified the need to restructure certain intelligent agents that make up the AIDA platform, in particular, agent 61 and agent 62, in order to avoid their obsolescence and ensure that they continue to respond to the functions assigned to them.

As mentioned earlier, these agents are primarily responsible for the interoperability of the AIDA platform using the HL7 protocol, where agent 62 enables the sending of messages and agent 61 is responsible for the processing of the messages. Failure of one of these agents in the hospital environment can be disastrous because communication with other hospital systems such as Picture Archiving and Communication System (PACS) or Laboratory Information System (LIS) is critical in providing quality health care to patients.

The main issues found in these agents were the fact that they were developed in the Visual Basic (VB) version 6 language and organized in an unstructured and inefficient way where some inconsistencies and redundancies were found. In the next subsection the main objectives to combat these problems will be outlined.

3.2 Solution Purposes

As the identification of the problem and its motivation have already been demonstrated, this section focuses on the definition of the objectives, the second stage of the DSR methodology. In this sense, the main objective of this study is the restructuring of the interoperability agents, not only by updating the software from the VB6 language to Java, in order to eliminate the sources of obsolescence and also to solve some compatibility issues (Java is platform-independent language), but also by removing redundant chunks of code and inconsistencies as well as adopting better approaches in order to eliminate sources of inefficiency and increase the performance of these agents.

So, after defining and clarifying the problem, as well as elucidating the needs and motivations of this study, it was proceeded to the identification of all objectives to fulfill in implementing the solution. These objectives include:

- Study and analysis of the status and functionalities of both agents, with the objective of identifying possible efficiency problems and, consequently, understanding what are the possible areas of intervention;
- Software update according to the hospital's needs, to combat obsolescence in CHUP hospital units;

• Guarantee the interoperability and integration of the different systems, in order to guarantee that the solutions fulfill the requirements for which they were initially developed and, thus, guarantee the effective provision of care.

3.3. Design and Development

In order to follow the technological advances of different hospitals, minimize medical errors and, consequently, improve the health care provided, it is essential to ensure that the AIDA platform is consistent and is able to guarantee the automation of information, interoperability and integration. Thus, and as previously mentioned, it is essential to have a systematic reassessment capable of determining that the technologies used are safe, effective, and economical compared to an alternative.

At the time of the CHUP reassessment, it was determined that the intelligent agents responsible for information exchange and interoperability between HIS through information standardization protocols (HL7) were on the verge of becoming obsolete, and as a result, the software upgrade was identified as an essential need.

For a conscious and efficient software update, it was necessary to analyze the environment in which these agents are implemented as well as the type of structure and responsibilities they presented. Following this careful analysis, it became clear that the software update of these intelligent agents should be from VB6 to the Java language.

The VB programming language is characterized as an event-oriented language with a syntax similar to English, which promotes clarity and legibility of the code. In addition, this language also has an Integrated Development Environment (IDE) that makes it easy to build the interface of any application [28]. This programming language had its last version, version 6.0, developed in 1998, however, since 2008, Microsoft, the company responsible for the development of this language, stopped supporting it [29].

On the other hand, Java is class based and object oriented, and it is designed to have as few implementation dependencies as possible [30]. This programming language shares many resources common to most programming languages in use today and is characterized as a general-purpose language, as it allows programmed content to be able to be executed anywhere, without system dependency [30] [31].

Both programming languages have their advantages and disadvantages. As a result, it was necessary to conduct a thorough analysis and consider all factors in order to make the best decision for software implementation. The presentation of the advantages and disadvantages of both languages are shown in Table 1 [29].

Table 1. Comparison between Java and VB6

	Advantages	**Disadvantages**
VB6	- Event-oriented language - Visual Basic code is easy to migrate to other languages - It has a very fast learning curve	- Not supported by Microsoft since March 2008 - It does not support process handling - Does not warn about certain errors or warnings - Only supported on 32-bit operating systems - Non-multiplatform language
Java	- Class-Based and Object-Oriented Language - Multiplatform language - Robust, designed to design very reliable software - Secure - Very fast learning curve	- It can be a slow-running language

Through the analysis of this table, it is possible to conclude that Java presents itself as a more advantageous and efficient programming language than the VB6 language, particularly in a clinical setting, due to its robustness and security. Nevertheless, the main reason for this migration was the fact that Java presents itself as a multiplatform language.

The migration from VB6 to the Java language should take place carefully since these types of programming languages are extremely different. Thus, in order to take advantage of the maximum resources and structure possible, the agents were re-registered.

Reutilization can be very beneficial for a successful conversion capable of meeting all the necessary objectives. In fact, in codes as extensive as these, the re-utilization of procedures, code or class modules can guarantee a reduction in effort and conversion time.

In a first step, the current VB6 application was studied to detect the blocks of code that needed to be changed, since it is an event-oriented language that moves to an object-oriented one. Accordingly, inactive, or duplicate code was removed so that there was no waste of time in converting uninteresting and unused code in these agents.

Subsequently, specific syntaxes were excluded since converting to Java would cease to have an effect, such as the ones corresponding to form modules like *FrmConfig.*

In the next step, the global variables declared that were not used were removed, as well as all the functions and subs that were not called in the main code. It is important to note that a function, unlike a sub, is characterized as a code structure capable of returning a certain value.

After carrying out all these changes, the different functions and subs were analyzed in order to find errors, inconsistencies and potential sources of inefficiency. After solving those issues, an attempt was made to optimize the code through the interconnection between functions and/or subs that had similar behavior to avoid repeating common code blocks with only minor variations. This interconnection was, in the great majority possible, through the use of global variables or the addition of certain arguments. In this way, it was possible to considerably reduce the amount of code of these agents as well as to remove some redundancy issues found in the code. Furthermore, the aggregation of similar functions and subs allowed a better code optimization in terms of performance and scalability, as it enabled the creation of a parameterization table within the hospital database. In this way, instead of having to change several functions/subs each time the hospital adopts a new partner, it is only necessary to add a new row in the hospital's database with the parameters of the new partner system.

To ensure interoperability and integration between the different systems, Structured Query Language (SQL) was used, a programming language based on relational algebra and relational calculation, so that, in this way, it was possible to manage the relational database and its manipulation. With this tool, a parameterization table was created for each of these agents, which enabled the connection between the different types of hospital services that exist and the hospital units where AIDA is present. Through this implementation, users of this platform can more easily activate or deactivate certain hospital services in a given health institution.

In a last step, the code was compiled and executed, with the development of different tests to find problems not previously detected and correct them to ensure that both agents worked as expected.

4. Results

The realization of this study allowed the conversion of intelligent agents from CHUP to a newer software, thus ensuring the elimination of the obsolescence problems to which the old software was subjected.

As mentioned in the previous section, it was removed the global variables, functions and subs not declared in the main code and tried to optimize them through the interconnection between functions and/or sub that had characteristics in common. In order to make these changes more visual and demonstrate the significant differences between the initial version of these agents and the one developed, the following graphs were created to present the balance between the initial and the final code. Figure 2 and 3 show the comparison between the number of variables, functions and subs in the initial and final solution for agent 61 and 62, respectively.

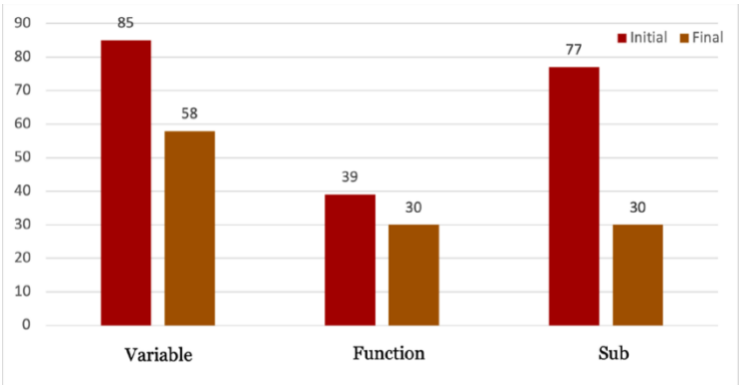

Fig. 3. Balancing of the amount of code between the initial and final version of agent 61.

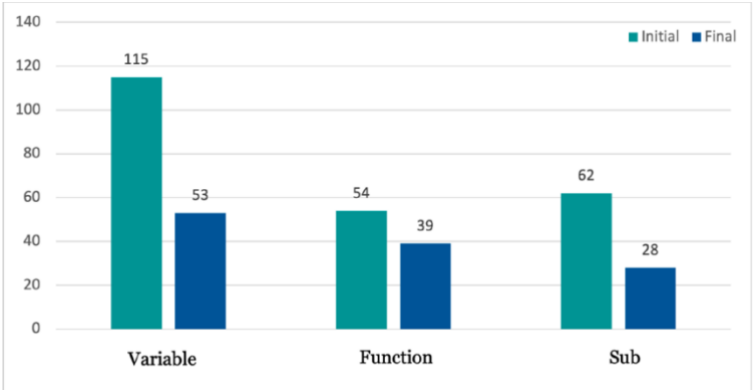

Fig. 4. Balancing of the amount of code between the initial and final version of agent 62.

Through all these measures described and with the analysis of the data presented, it became possible to optimize the agents 61 and 62, making them more agile and effective while still meeting the needs for which they were initially designed. Consistently, the execution of this reformulation of the agents enabled the continuity of hospital services and the avoidance of unnecessary failures, thus promoting quality in decision support and clinical practice.

In the future, it is, therefore, essential to carry out the conversion of all agents that make up the AIDA platform, in order to guarantee the correct functioning of the health care flow allowing health professionals to access the necessary information for clinical decision making and, consequently, providing efficient health care.

5. Conclusion

With the constant technological and scientific advances, the technologies implemented in any organization, such as health institutions, require constant maintenance and progress so that, in this way, they can follow the exponential evolution felt nowadays. In this way, it becomes essential that organizations are able to respond to the needs that arise with this technological progress, such as allowing the correction of errors that arise from the implemented measures, as well as allowing the change of technologies that become obsolete and unable to meet the organization's needs. To this end, the presence of continuous maintenance of an organization's technologies may be the key to success.

In a hospital unit, maintenance and HTA processes ensure that the technology remains safe and effective, that the cost-benefit ratio of the technology is positive, and that the systems are changed before they are even considered obsolete. Thus, the efficiency of the provision of health care and, consequently, the health status of the patient are ensured.

The case study presented in this article made it possible to perceive the need for these reformulations in the health systems of the CHUP units. The analysis and assessment of agents 61 and 62 from the AIDA platform allowed to keep up with the technological advances and to take the best of them, removing potential sources of obsolescence and redundancy problems, and ensuring interoperability and integration between different systems.

Through a positive balance of this implementation, we intend to continue updating the AIDA platform and extend this change to all intelligent agents in the CHUP hospital units. Following a successful implementation in this hospital, the upgraded AIDA platform will be migrated to the remaining hospitals where this platform is being used. In the future, it is also planned to implement an activity and error log record of these agents in a NoSQL database using Elasticsearch because it allows for the storage, search, and analysis of massive volumes of data quickly and in near real-time. It is then intended to perform a visual exploration and analysis of these data using Kibana in order to monitor the behavior of these agents in real time using dashboards, aggregators, and data filtering.

As a result of converting all agents to the Java language and addressing their redundancy and information disorganization issues, obsolescence was completely eliminated from this software, so that compliance is guaranteed in all technological solutions implemented in the CHUP.

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Aims and Objectives

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