Article

A Holistic Cybersecurity Maturity Assessment Framework for Higher Education Institutions

Aliyu Aliyu[1], **Leandros Maglaras** [1]*, **Ying He**[1]*, **Iryna Yevseyeva** [1], **Eerke Boiten** [1]. **Allan Cook**[1] **and Helge Janicke** [1],

[1] School of Computer Science and Informatics, De Montfort University, Leicester LE1 9BH, UK
* Correspondence: leandros.maglaras@dmu.ac.uk; ying.he@dmu.ac.uk

Abstract: As organisations are vulnerable to cyber attacks, their protection becomes a significant issue. Capability Maturity Models can enable organisations to benchmark current maturity levels against best practices. Although many maturity models have been already proposed in the literature, a need for models that integrate several regulations exists. This article presents a light web-based model that can be used as a cyber security assessment tool for Higher Education Institutes (HEIs) of the UK. The novel Holistic Cybersecurity Maturity Assessment Framework incorporates all security and privacy regulations and best practises that HEIs must be compliant to, and can be used as a self assessment or a cybersecurity audit tool.

Keywords: Assessment Framework; Cyber Security; GDPR; PCI-DSS; DSPT; NISD

1. Introduction

In an age of information growth, technology plays a key role in shaping all aspects of human life. In the education sector, teachers and students can make use of the ever-expanding resources available, creating a diverse learning experience that caters for many teaching and learning styles. However, with this adoption of technology Higher Education Institutions (HEIs) are finding themselves the targets of malicious cyber activities, with a recent JISC report [1] reaffirming that UK universities are not well prepared to defend against, or recover from cyber attacks.

Due to their nature, HEIs hold a significant amount of information and accumulated knowledge. As a result they are attractive to threat actors who target research findings, financial data and computing resources. Katz [2] identified that universities are under continual risk of cyber attacks. Consequently, HEIs face a constant challenge of balancing public access in the interest of sharing information, whilst protecting their information assets.

A study of businesses students in New England was conducted by Kim [3] on the attitude of students regarding Information Security Awareness (ISA). It was evident in the findings that students who participated found the ISA training important and necessary in improving their knowledge in cyber security. Studies in 2013 by the Kaspersky Lab [4] showed over a period of a year, 91% of organisations surveyed reported their IT infrastructure had been the victim of at least one cyber-attack. Additionally, stated in the report, there was an increase in cybercrime such as email phishing, unauthorised network access, malware and theft of mobiles in 2013 compared to 2012. The study focused on corporate IT infrastructures and it highlighted that for years, IT infrastructures such as those in HEIs had been deficient in terms of security and had always been a target for threat actors.

In the market, there are currently many frameworks available for organisations to adopt to improve the effectiveness of their cyber security. These frameworks support action at both an individual and organisational level. Aloul[5] highlights that for the success and security of any security improvement programme adopted by an institution, it is important that students and staff are given training and education in information security awareness. This should be made part of the risk/security assessment plan adopted by all levels of administration,

from students to teachers and all administrative employees as teaching the front-end users, will serve as the first line of defence against attackers.

To build a secure environment, providing relevant security awareness program is the initial step. There should be constant training and education provided to equip students, staff and employees to deal with the latest cyber threats and modern prevention methods. There should also be effectiveness metrics that the institution can measure and monitor. Changes to management and audits can be adopted by the institution to strengthen the level of cyber security[6]. One important set of tools that Universities can use in order to measure their cyber security readiness and compliance levels is maturity models.

Matthew J. Butkovic[7] defined the maturity model as "a set of characteristics, attributes, indicators, or patterns that represent progression and achievement in a particular domain or discipline". The artifacts that make up the model are typically agreed on by the domain or discipline, which validates them through application and iterative re-calibration. In order to make maturity models more effective, the measurable transitions between levels should be based on empirical data that have been validated in practice. This means each level in the model should be more mature than the previous level. In essence, what constitutes mature behaviours must be characterized and validated. This can be challenging to achieve unambiguously in many maturity models.

Our proposed Holistic Cybersecurity Maturity Assessment Framework (HCYMAF) is based on a process methodology called a Capability Maturity Model (CMM) [8]. CMMs were originally developed by the Carnegie Mellon University Software Engineering Institute (CMU/SEI) to improve the management of software development and have been subsequently used in many other domains, such as cyber security. A maturity model defines a set of metrics for measuring organisational competency or maturity in terms of a set of recognised best practices, skills or standards. Metrics are organised into categories and quantified on a performance scale. Using specific rating criteria organisations can measure their performance against these maturity levels.

This paper makes the following contributions,

- It proposes a novel Holistic Cybersecurity Maturity Assessment Framework (HCYMAF) for HEIs that can be used in order to conduct a gap analysis against 15 security requirements.
- The proposed framework incorporates several regulations and security best practices into one lightweight online self assessment guide.
- It produces compliance reports against all regulations that the HEI must be compliant with in order to facilitate mitigation plans.
- It can be adapted and expanded in order to be used on other critical sectors of the UK and abroad.

The rest of the paper is organised as follows: in Section 2 we present related work while in Section 3 we describe our system framework. In Sections 3.4 we present the validation procedure. Finally in Section 5 we conclude this paper and present future work.

2. Related Work

2.1. Essential Components of a Maturity Model

A maturity model should follow a structure to ensure its consistency. It typically includes the components, levels, attributes, appraisal and scoring methods, and model domains. Levels represent the measurement aspect of a maturity model, however if the scaling is inaccurate or incomplete, we may not be able to validate the model and the results produced may not be accurate or consistent.

Attributes represent the main content of the model and are classified by domains and levels. Attributes are defined at the intersection of a domain and a maturity level, which are typically based on observed practice, standards, or other expert knowledge. These can be expressed as characteristics, indicators, practices, or processes. In capability maturity models, attributes also express qualities of organisational maturity (e.g. planning and measuring) for supporting process improvement regardless of the process being modelled.

Appraisal and scoring methods are used to facilitate the assessment. They can be formal or informal, expert-led or self-applied. Scoring methods are algorithms devised by the community to ensure consistency of appraisals and they are common standards for measurement. Scoring methods can include weighting (so that

important attributes are valued over less important ones) or can value different types of data collection in different ways (e.g. providing higher marks for documented evidence than for interview-based data).

Model domains essentially define the scope of a maturity model. Domains are a means for grouping attributes into an area of importance for the subject matter and intent of the model. In capability models, the domains are often (but not necessarily) referred to as process areas as they are a collection of processes that make up a larger process or discipline (e.g. software engineering). Depending on the model, users may be able to focus on improving a single domain or a group of domains.

2.2. Maturity Model Types

Caralli [9] classified maturity models into three different types, progression models, capability models and hybrid models. Progression models represent a simple progression or scaling of a characteristic, indicator, attribute, or pattern in which the movement through the maturity levels indicates some progression of attribute maturity. Progression models typically place their focus on the evolution of the model's core subject matter (such as practices or technologies) rather than attributes that define maturity (such as the ability and willingness to perform a practice, the degree to which a practice is validated, etc.). In other words, the purpose of a progression model is to provide a simple road map of progression or improvement as expressed by increasingly better versions (for example, more complete, more advanced) of an attribute as the scale progresses [7].

For the capability models such as CMM, the dimension that is being measured is a representation of organisational capability around a set of characteristics, indicators, attributes, or patterns, often expressed as processes. A CMM measures more than the ability to perform a task; it also focuses on broader organisational capabilities that reflect the maturity of the culture and the degree to which the capabilities are embedded (or institutionalised) in the culture [7]. Hybrid models merge two abilities; the ability to measure maturity attributes and the ability to measure evolution or progression in progressive models. This type of model reflects transitions between levels that are similar to capability model levels (i.e., that describe capability maturity) but also account for the evolution of attributes in a progression model. [7]

2.3. Existing work on maturity models

Evaluation of maturity capability was developed in 1986 by the US Department of Defense for assessing maturity capabilities of Software Engineering processes of the software companies they worked with [10]. This model was later adopted by different domains including cyber security.

Various cyber security maturity models were developed according to the needs of organisations. Currently, the most popular and widely used maturity models are incorporated into (inter)national standards. For instance, ISO/IEC 27001 [11,12] and NIST [13]; European and American standards for cyber security respectively. ISO/IEC 27001 was developed based on the British Standard BS7799 and ISO/IEC 17799 to provide requirements, maintain and improve Information Security Management System (ISMS) [10]. ISO/IEC 27001 defines ISMS as a part of the overall management system, which "establish, implement, operate, monitor, review, maintain and improve information security" [11,12].

Sabillon, et al [14] proposed a Cyber Security Audit Model (CSAM) in order to improve cybersecurity assurance. The CSAM was designed to be used for conducting cybersecurity audits in organisations and Nation States. CSAM evaluates and validates audit, preventive, forensic and detective controls for all organisational functional areas. The CSAM was then tested, implemented and validated along with the Cybersecurity Awareness TRAining Model (CATRAM) in a Canadian higher education institution. Adler, et al [15] created a Dynamic Capability Maturity Model for Improving Cyber Security. It extends an existing Cyber Security CMM into a dynamic performance management framework. It is a software based framework that enables organisations to create, test, validate or refine plans to improve their Cyber Security maturity levels. Almuhammadi, et al identified the gaps of the NIST Cyber Security Framework for Critical Infrastructure (NIST CSF) by comparing it to the COBIT, ISO/IEC 27001 and ISF frameworks, and then proposed an information security maturity model (ISMM) to fill in the gaps and measure NIST CSF implementation progress [16]. Miron, et al reviewed Cybersecurity Capability Maturity Models for providers of critical infrastructure, and provided recommendations on employing capability maturity models to measure and communicate readiness [17].

Akinsanya, et al investigated the effective assessment of healthcare cyber security maturity models for healthcare organisations using cloud computing [18]. The finding showed that the assessment practices are sometimes considered not effective as the measurements of individual IS components were not capable of depicting the overall security posture within a healthcare organisation. The effects of cloud computing technology in healthcare was also not taken into account.

The existing maturity models offer a manageable approach for assessing the security level of a system or organisation, however it is difficult to establish sound security models and mechanisms for protecting the cyberspace, as the definitions and scopes of both cyberspace and cyber security are still not well-defined [19]. Most of the existing maturity models provide a minimum compliance model rather than an aspired cyber security model that can address emerging threat landscape. The model should allow multi-users including, management, security experts and practitioners to assess the overall security status of the organisation/system and taking security measures to address the weaknesses identified from the assessment. Most of the existing models are measured by qualitative metrics/processes, however quantitative metrics should be essential for security assessment[19].

2.4. Selected existing models adopted for HEIs maturity assessment

Existing models were reviewed for their applicability for HEIs maturity assessment. The basis of our maturity model was formed according to the CMMI [20]. The CMMI was used as it provides an evolutionary path to performance improvement.

The starting point of a cybersecurity assessment is definition of requirements for an Information Security Management System (ISMS) of an organisation. ISO/IEC 27001 Information Security Management [11,12] is the best-known standard for providing a set of necessary requirements and this was used in our framework.

In addition to the evaluation of maturity, our model provides a set of cybersecurity actions and controls to be implemented to close the existing gaps in an HEI cyber security. For this we reviewed a number of well established models and selected the most critical ones to be used for HEIs protection from known cyber-attack vectors. The CIS Controls [21] are specifically technical controls that can be used to mitigate from specific attacks. ENISA's guidelines on assessing DSP security and OES compliance with the NISD security requirements [22] provided insight into the self-assessment/management framework for the DSP security against the security requirements. The cyber security evaluation tool provided a systematic approach for evaluating an organisation's security posture by assessing operational resilience, cybersecurity practices, organisational management of external dependencies, and other key elements of a robust cybersecurity framework.

Except from the above models, Citigroup's Information Security Evaluation Model (CITI-ISEM) [23], Computer Emergency Response Team / CSO Online at Carnegie Mellon University (CERT/CSO), The U.S. Cybersecurity Capability Maturity Model (C2M2) and its National Initiative for Cybersecurity Education's Capability Maturity Model (NICE-CMM) were also reviewed [23]. These models were reviewed in order to check that we did not miss any important security controls from incorporating them into our framework.

The work of Mbanaso et al. titled Conceptual Design of a Cybersecurity Resilience Maturity Measurement (CRMM) Framework [24] was also reviewed and it provided insight into measuring the effectiveness and efficiency of organisation's controls with respect to cybersecurity resilience, and also the steps that can be taken to improve resilience maturity. Lastly, the work of Butkovic and Caralli titled Advancing Cybersecurity Capability Measurement Using the CERT-RMM Maturity Indicator Level Scale [25] provided insight into how the CMMI maturity levels can be utilised to show incremental improvement in maturity.

Recently ENISA [26] has published a report that presents a mapping of the main security objectives, between the NISD and the GDPR in order to support organisations in their process of identifying appropriate security measures. On the same time ISO issued the ISO 27701 Standard [27] in order to help organisation establish, implement, maintain and continually improve a Privacy Information Management System by combining the ISMS with the privacy framework and principles defined in ISO/IEC 29100. NIST has also published the Privacy Framework [28] that follows the structure of the Framework for Improving Critical Infrastructure Cybersecurity (the Cybersecurity Framework) in order to facilitate the use of both frameworks together. It is obvious that all major security organisations and authorities have identified the need for mapping cyber securoty requirements

from different frameworks, but until now only initial works that map GDPR with NIST and NISD have been published.

3. Proposed Maturity Framework

An appraisal is an activity that helps identify the strengths and weaknesses of an organisation's processes and to examine how closely the processes relate to identified best practices. Appraisals are typically conducted to determine how well the organisation's processes are when compared to related identified security best practices, and identify areas where improvement can be made. Our proposed Maturity Assessment Framework (MAF) can be used in order to inform external customers and suppliers about how well the organisation's processes are when compared to related identified best security practices. The model can also be used as a gap analysis and compliance checking tool that any organisation can use in order to define how well contractual requirements are met. The MAF is established based on the following,

- A review of security requirements that HEIs must follow in order to demonstrate compliance with the General Data Protection Regulation (GDPR), Payment Card Industry Data Security Standard (PCI DSS), Data Security and Protection Toolkit (DSPT) and any other regulation that may apply to them;
- A literature review of existing research on maturity models in cyber security as well as in other areas.

This framework entitled "A Holistic Cybersecurity Maturity Assessment Framework (HCYMAF) for Higher Education Institutes (HEIs)" aims at designing a cyber security maturity assessment framework for all higher education institutes in the United Kingdom. The framework can be used as a self-assessment tool by the HEIs organisation in order to establish their security level and highlight the weaknesses and mitigation plans that need to be implemented. The framework is a mapping and codification tool for HEIs against all regulations that the HEIs must comply with, such as the GDPR, PCI DSS, DSPT etc.

The framework uses 6 different levels of maturity against which the cyber security performance of each organisation can be measured. The framework will be validated through 3 pilot implementations, of which 1 has already been conducted with positive results and feedback obtained. This model is important and novel because HEIs, by using this framework will be able to assess the security level of their organisation, conduct a gap analysis and also create appropriate mitigation plans. The model also informs whether the organisation is compliant with the expected regulations thus helping them in self-assessment and improvement by producing relevant compliance reports.

It is necessary to design a maturity model that will be able to facilitate the organisations and the National Cyber Security Center (NCSC) of the UK in order to achieve the objectives mentioned above. To achieve this, the model must have the following characteristics. It must:

- Cover the full extent of the requirements of the different regulations;
- Be able to be used as a self-assessment tool
- Be able to be used as a basis for an independent assessment
- Provide clear results regarding the security posture of the organisations
- Produce compliance reports
- Be able to be used as guidance for implementation of a concrete security policy by the HEIs
- Be measurable
- Be easily extractable and reusable

3.1. Security Requirements

As illustrated in Figure 1, the proposed maturity assessment model has 15 requirements. The 15 requirements followed are categorised as 'General Security Requirements'. The General Security Requirements which is the foundation of the model is based on cyber security best practices such as the CIS Controls, NIST Framework, etc. The 15 requirements were divided into 3 groups. IDENTIFY (I), PROTECT & DETECT (P), and RESPOND & RECOVER (R). It should be noted that the DETECT controls of NIST were merged into our protect & detect requirements in order to keep our model lightweight.

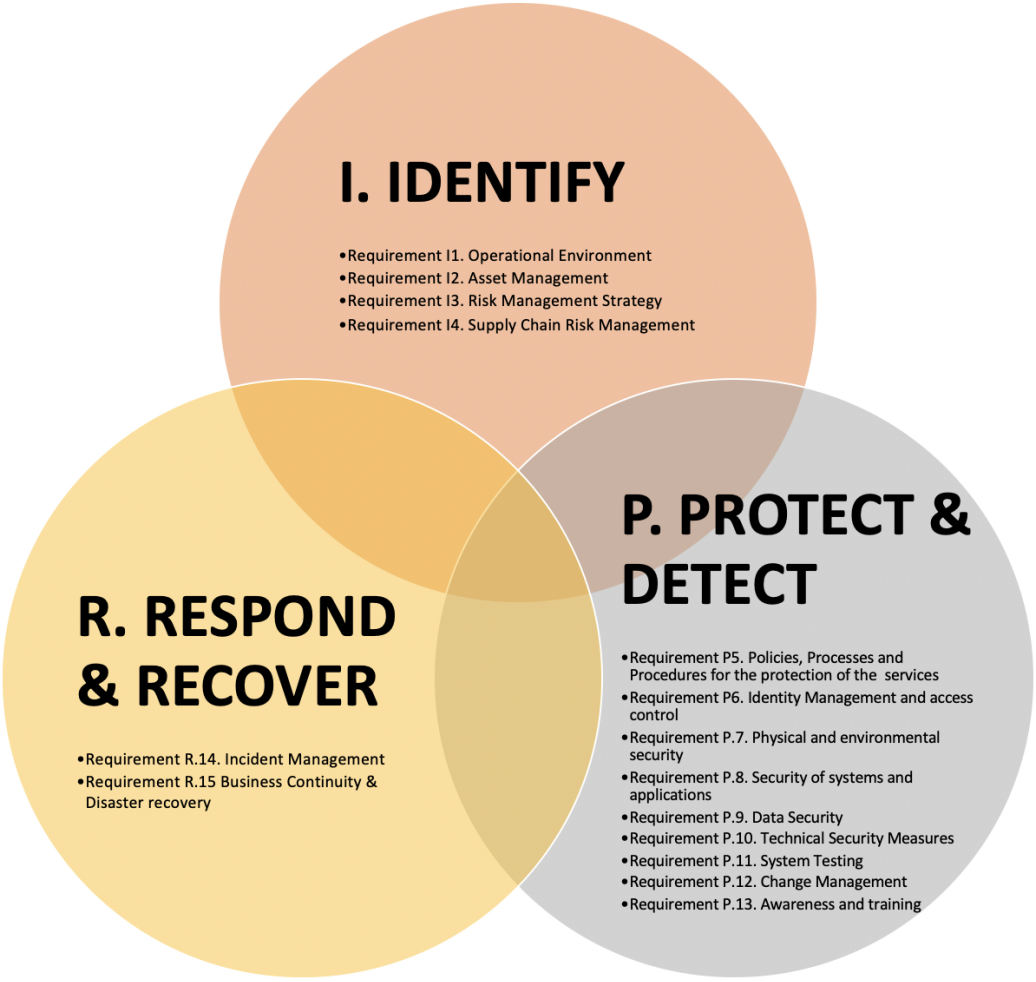

Figure 1. Proposed Maturity Model

Requirements 1-4 fall under Identify i.e. I1 to I4, Requirements 5-13 fall under Protect & Detect i.e. P5 to P13 whilst Requirements 14-15 fall under Respond & Recover i.e. R14 to R15. All the requirements of Identify i.e. Requirement I1. Operational Environment; Requirement I2. Asset Management; Requirement I3. Risk Management Strategy; and Requirement I4. Supply Chain Risk Management, are necessary for the facilitation of the understanding of the business and operational ecosystem of the organisation.

All the requirements of Protect & Detect i.e. Requirement P5. Policies, Processes and Procedures for the protection of the services; Requirement P6. Identity Management and access control; Requirement P7. Physical and environmental security; Requirement P8. Security of systems and applications; Requirement P9. Data Security; Requirement P10. Technical Security Measures; Requirement P11. System Testing; Requirement P12. Change Management; and Requirement P13. Awareness and training; are necessary in order to detect incidents and protect all assets supporting the services of the organisation i.e. (people, procedures and technologies).

Lastly, all the requirements of Respond & Recover i.e. Requirement R14. Incident Management; and Requirement R15. Business Continuity & Disaster Recovery, are necessary in order to respond and manage an information security incident that may have the ability to influence the provision of the services offered by the HEIs. Finally, it should be noted that some requirements do have sub-requirements.

3.2. Mapping of Regulations

It is worth stating that we incorporated the regulation requirements of GDPR, PCI DSS and DSPT into our General Security Requirements. This was done by focusing on each individual regulation and mapping it into one of our requirements. For example, in terms of GDPR, we focused on the 7 principles of GDPR,

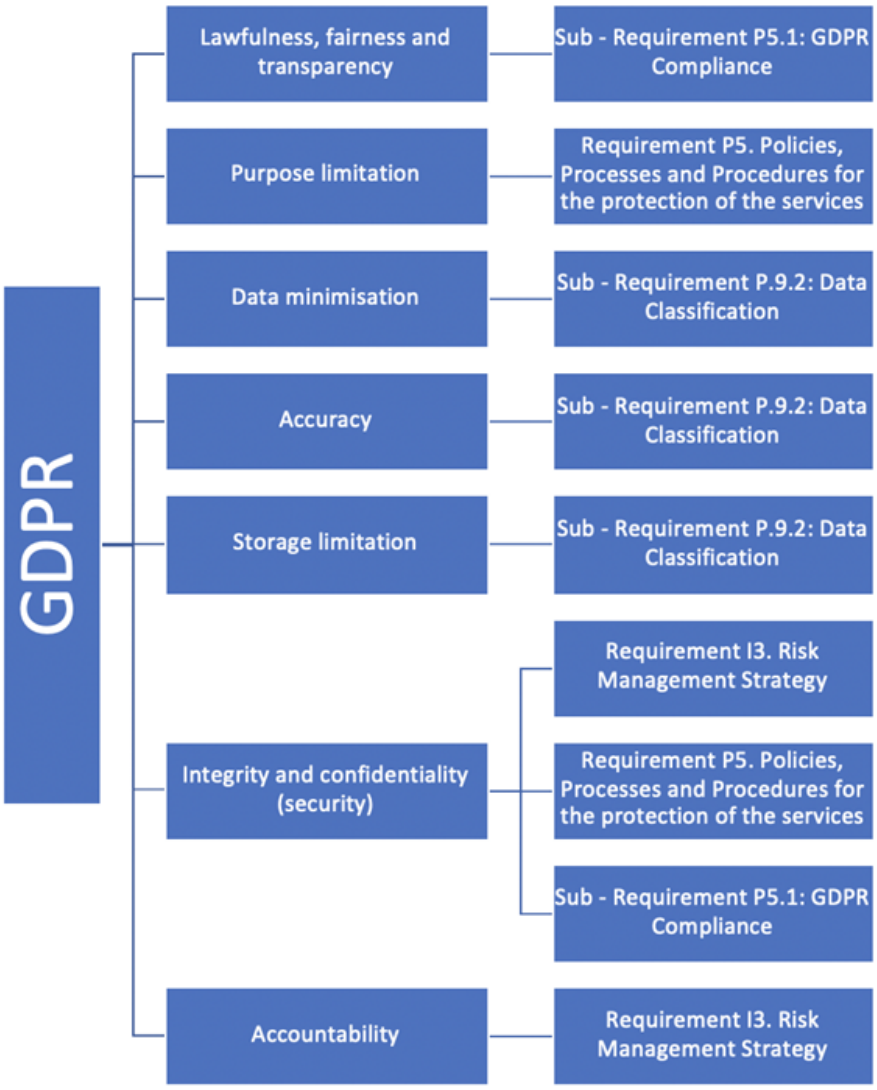

Figure 2. GDPR Mapping

as shown in Figure 2 and mapped each of the principles into one of our requirements. For example, the first principle of GDPR is lawfulness, fairness and transparency. This was mapped into Sub-Requirement P5.1: GDPR Compliance. The second principle which is purpose limitation was mapped into Requirement P5. Policies, Processes and Procedures for the protection of the services, and so on.

In terms of incorporating PCI DSS. We focused on the 6 principles of PCI DSS, as each of these principles had its requirements. In terms of incorporating DSPT, we also focused on the 10 principles of the regulation and likewise each of those principles were mapped into one of our requirements. Overall, all the aforementioned regulations were incorporated into our model and merged to form a solid maturity model as illustrated in Figure 3.

3.3. Maturity levels

The maturity model has its maturity levels. This means that each of the requirements and sub requirements has its own maturity levels. The maturity levels are 6 scores, from 0 to 5, with 0 being the lowest while 5 being the highest. Each of these maturity levels has a meaning, it represents a staged path for an organisation's performance and process improvement efforts based on predefined sets of practice areas. Each maturity level

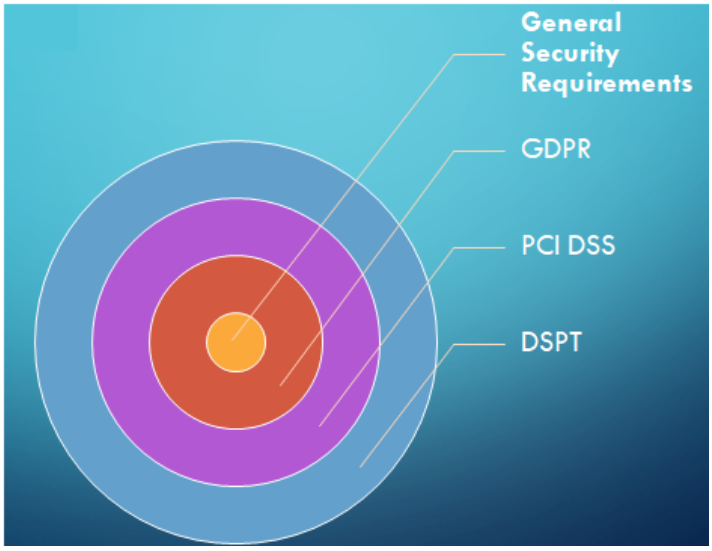

Figure 3. Merging of different requirements into the proposed Holistic Cybersecurity Maturity Framework

also builds on the previous maturity levels by adding new requirements. An example of such a scale is shown in Figure 4 below. A brief description of each level is presented:

- Level 0: Incomplete; Ad hoc and unknown. Work may or may not get completed.
- Level 1: Initial; Unpredictable and reactive. Work gets completed but is often delayed and over budget.
- Level 2: Managed; Projects are planned, performed, measured, and controlled.
- Level 3: Defined; the organisation is proactive, rather than reactive. There are organisation-wide standards which provide guidance across projects, programs, and portfolios.
- Level 4: Quantitatively Managed; the organisation is data-driven with quantitative performance improvement objectives that are predictable and align to meet the needs of internal and external stakeholders.
- Level 5: Optimising; the organisation is focused on continuous improvement and is built to pivot and respond to opportunity and change.

In terms of evaluation of the performance of an organisation against an individual requirement, the maturity notes should be read one at a time in ascending order (from 0 to 5). If all notes are fulfilled, then the next level should be read and examined. In order to assign a certain score, all of the lower levels must be completely fulfilled first. It should also be noted that some sub-requirements have a Not Applicable (N/A) option, this is because not all sub-requirements are applicable to every organisation.

3.4. Evaluation and Validation

Before the model is released to the HEIs, it should be validated through pilot implementations. The model should be possible to be used by organisations of different sises and regardless of the activities they have, e.g. provide health studies. The team at De Montfort University (DMU) that is designing the HCYMAF in cooperation with the NCSC will run three pilots following this tasks list:

1. Selection of the pilots
2. Notification of the pilots
3. Compilation of the team that will conduct the assessment
4. Implementation of the assessment
5. Communication of the results

In the meantime, the DMU team is building a website which HEIs will use in order to perform self-assessments and receive in a graphical model result and a gap analysis that showcases the sectors that need immediate actions. Also compliance reports will be produced automatically from the HCYMAF, giving the

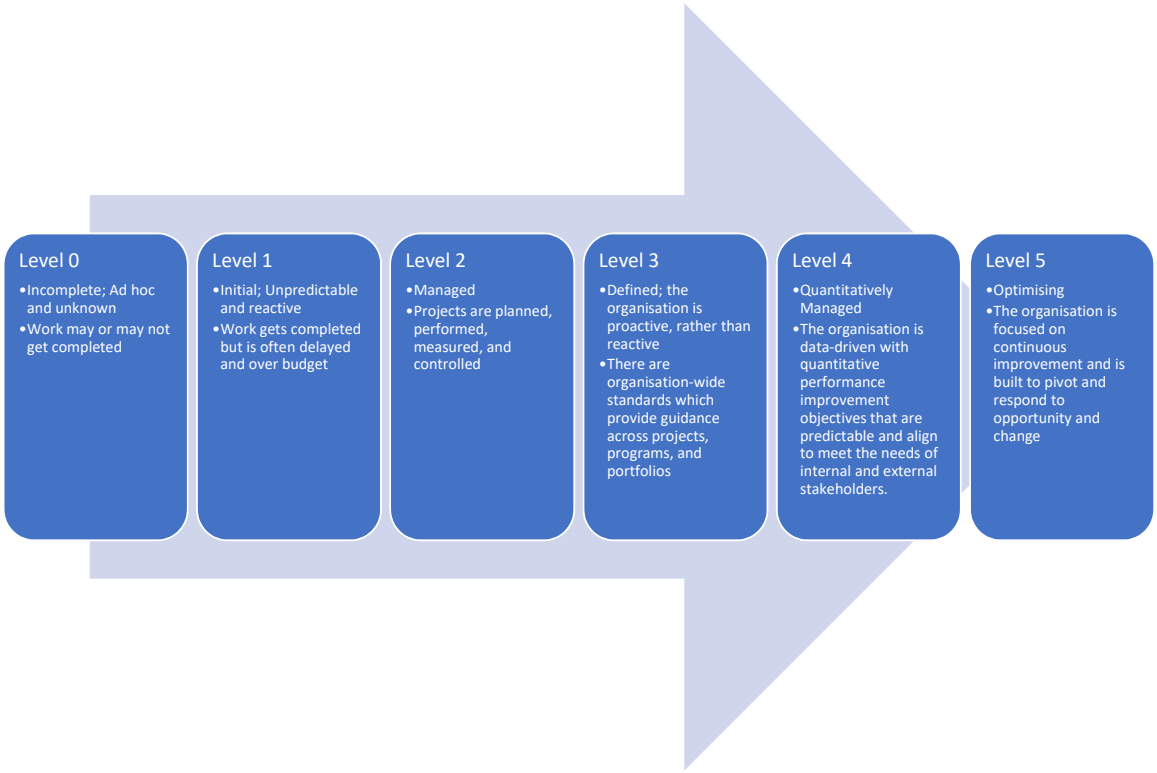

Figure 4. Maturity levels of the proposed model

opportunity to the organisation to react fast and avoid penalties. Each HEI representative will need to register to the platform and then go through the guide. The process can be paused and continued in a later time, since a lot of information and time is needed in order to conduct a full cyber security assessment. The results for each organisation are only visible to the organisation along with charts and reports that will help the security and data protection officers to take the appropriate measures. Aggregated results will be collected and used for analysis by the NCSC in order to prioritise future security plans.

4. Discussion

Our proposed framework defines a set of metrics for measuring organisational competency or maturity in terms of a set of recognised best practices, skills or standards. It has incorporated the General Data Protection Regulation (GDPR), Payment Card Industry Data Security Standard (PCI DSS), Data Security and Protection Toolkit (DSPT) and can be used in order to conduct a gap analysis against 15 security requirements. The metrics are organised into categories and quantified on a performance scale. The measurable transitions between levels are based on empirical data that have been validated in practice, and each level in the model is more mature than the previous level.

By applying the proposed framework, organisations can achieve progressive improvements in their cybersecurity maturity by first achieving stability at the project level and continuing to the most advanced-level, organisation-wide continuous process improvement, using both quantitative and qualitative data to make decisions. For instance, at maturity level 2, the organisation has been elevated from ad hoc to managed by establishing sound security controls, procedures and processess. As a University achieves the generic and specific goals in a maturity level, it is increasing its maturity and at the same time achieves compliance with relevant regulations and national laws.

Based on the experience we will gain out of this project, we will adapt the proposed HCYMAF for organisations in other sectors e.g. water, power suppliers, etc in the future. We will incorporate the best practices, skills or standards that are essential for different sectors. We also aim to create (working closely with the NCSC) a semi-automated self-assessment online framework. This online framework could be used by all

critical organisations in the UK. The framework will include specific controls like IoT, SCADA etc. where each organisation will fill the controls that are applicable to them. Finally, the information collected by this online tool will help the UK government to prioritise the mitigation plans related to security that need to be taken in a national level in terms of funding specific actions, launch new security tools etc.

5. Conclusions

There have been a number of cyber-attacks upon HEIs around the globe, and the recent JISC report reaffirmed that UK universities are not well prepared to defend against, or recover from, cyber attacks. Capability Maturity Models can enable organisations to benchmark current maturity levels against best practices. Although many maturity models have been already proposed in the literature, no model that integrates several regulations exists. Based on this finding, in this article we present a light web-based model that can be used as a cyber security assessment tool for Higher Education Institutes (HEIs) of the UK that incorporates all security and privacy regulations and best practises that HEIs must be compliant with.

The proposed model consists of 15 security categories, 6 maturity levels and is implemented on an online platform that can be used both as a self assessment and audit tool, facilitating organisations perform a gap analysis, receive automated compliance reports and graphical representation of their security posture. Information that will be collected from the platform can be used, after proper aggregation and anonymisation processes, from the NCSC in order to identify current security problems and prioritise future security plans and funding actions.

Author Contributions: Conceptualization,A. A., Y. H., and L.M.; Methodology, A. A., L. M., Y. H. and A. C.; Software, A. A., I. Y., and L.M.; Validation, H. J., E. B, A. C., and L. M.; formal analysis, A. A. and H. J., investigation, A. A., Y. H., and I. Y.; resources, A. A., Y. H., I. Y. and A. C.; data curation, A. A., and L. M.; writing—original draft preparation, A. A., Y. H, I. Y., and L. M.; writing—review and editing, E. B., H. J., and A. C.; visualization, A. A., and Y. H.; supervision, L. M.

Funding: We thankfully acknowledge the support of the NCSC funded project (RFA: 20058).

Conflicts of Interest: All authors declare no conflict of interest.

References

1. Chapman, J.; Francis, J. *Cyber security posture survey results 2019*; Joint Information Systems Committee (JISC), 2019.
2. Katz, F.H. The effect of a university information security survey on instruction methods in information security. Proceedings of the 2nd annual conference on Information security curriculum development, 2005, pp. 43–48.
3. Kim, E.B. Recommendations for information security awareness training for college students. *Information Management & Computer Security* **2014**.
4. Kaspersky, G.C.I. *Global Corporate IT Security Risks: 2013*; Kaspersky Lab, 2013.
5. Aloul, F.A. The need for effective information security awareness. *Journal of Advances in Information Technology* **2012**, *3*, 176–183.
6. Rajewski, J. Cyber security awareness: Why higher education institutions need to address digital threats, 2013.
7. Butkovic, M.J.; Caralli, R.A. Advancing Cybersecurity Capability Measurement Using the CERT-RMM Maturity Indicator Level Scale **2013**.
8. Humphrey, W. Characterizing the software process: a maturity framework. *IEEE Software* **1988**, *5*, 73–79. doi:10.1109/52.2014.
9. Caralli, R.; Knight, M.; Montgomery, A. Maturity models 101: A primer for applying maturity models to smart grid security, resilience, and interoperability. Technical report, CARNEGIE-MELLON UNIV PITTSBURGH PA SOFTWARE ENGINEERING INST, 2012.
10. Proença, D.; Borbinha, J. Information Security Management Systems - A Maturity Model Based on ISO/IEC 27001. Business Information Systems; Abramowicz, W.; Paschke, A., Eds.; Springer International Publishing: Cham, 2018; pp. 102–114.
11. Humphreys, E. *Implementing the ISO/IEC 27001: 2013 ISMS Standard*; Artech House, 2016.
12. Brewer, D. *An Introduction to ISO/IEC 27001: 2013*; BSI Standard Limited, 2013.
13. Barrett, M. Framework for improving critical infrastructure cybersecurity. *National Institute of Standards and Technology, Gaithersburg, MD, USA, Tech. Rep* **2018**.

14. Sabillon, R.; Serra-Ruiz, J.; Cavaller, V.; Cano, J. A comprehensive cybersecurity audit model to improve cybersecurity assurance: The cybersecurity audit model (CSAM). 2017 International Conference on Information Systems and Computer Science (INCISCOS). IEEE, 2017, pp. 253–259.
15. Adler, R.M. A dynamic capability maturity model for improving cyber security. 2013 IEEE International Conference on Technologies for Homeland Security (HST). IEEE, 2013, pp. 230–235.
16. Almuhammadi, S.; Alsaleh, M. Information security maturity model for NIST cyber security framework. *Computer Science & Information Technology (CS & IT)* **2017**, *7*, 51–62.
17. Miron, W.; Muita, K. Cybersecurity capability maturity models for providers of critical infrastructure. *Technology Innovation Management Review* **2014**, *4*.
18. Akinsanya, O.O.; Papadaki, M.; Sun, L. Current Cybersecurity Maturity Models: How Effective in Healthcare Cloud? CERC, 2019, pp. 211–222.
19. Le, N.T.; Hoang, D.B. Can maturity models support cyber security? 2016 IEEE 35th international performance computing and communications conference (IPCCC). IEEE, 2016, pp. 1–7.
20. Team, C.P. Capability maturity model® integration (CMMI SM), version 1.1. *CMMI for Systems Engineering, Software Engineering, Integrated Product and Process Development, and Supplier Sourcing (CMMI-SE/SW/IPPD/SS, V1. 1)* **2002**.
21. Keller, N. CIS Controls Informative Reference Details **2019**.
22. ENISA. *Guidelines on assessing DSP security and OES compliance with the NISD security requirements*; European Union Agency For Network and Information Security, 2018.
23. Miron, W.; Muita, K. Cybersecurity Capability Maturity Models for Providers of Critical Infrastructure. *Technology Innovation Management Review* **2014**, *4*, 33–39. doi:http://doi.org/10.22215/timreview/837.
24. Mbanaso, U.M.; Abrahams, L.; Apene, O.Z. Conceptual Design of a Cybersecurity Resilience Maturity Measurement (CRMM) Framework. *The African Journal of Information and Communication* **2019**, p. 1–26. doi:10.23962/10539/27535.
25. Butkovic, M.; Caralli, R. Advancing Cybersecurity Capability Measurement Using the CERT-RMM Maturity Indicator Level Scale. Technical Report CMU/SEI-2013-TN-028, Software Engineering Institute, Carnegie Mellon University, Pittsburgh, PA, 2013.
26. Markopoulou, D.; Papakonstantinou, V.; de Hert, P. The new EU cybersecurity framework: The NIS Directive, ENISA's role and the General Data Protection Regulation. *Computer Law & Security Review* **2019**, *35*, 105336.
27. Lachaud, E. ISO/IEC 27701: Threats and opportunities for GDPR certification. *Available at SSRN* **2020**.
28. Hiller, J.S.; Russell, R.S. Privacy in crises: The NIST privacy framework. *Journal of Contingencies and Crisis Management* **2017**, *25*, 31–38.