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The mission of the IJISPM - International Journal of Information Systems and Project Management - is the dissemination of new scientific knowledge on information systems management and project management, encouraging further progress in theory and practice.

The IJISPM publishes leading scholarly and practical research articles that aim to advance the information systems management and project management fields of knowledge, featuring state-of-the-art research, theories, approaches, methodologies, techniques, and applications.

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Authors are encouraged to submit articles on information technology governance, information systems planning, information systems design and implementation, information technology outsourcing, project environment, project management life-cycle, project management knowledge areas, criteria and factors for success, social aspects, chief information officer role, chief information officer skills, project manager role, project manager skills, among others.

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- project execution
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Editorial

The mission of the *IJISPM - International Journal of Information Systems and Project Management* is the dissemination of new scientific knowledge on information systems management and project management, encouraging further progress in theory and practice.

It is our great pleasure to bring you the third number of the seventh volume of IJISPM. In this issue, readers will find important contributions on information systems research opportunities, information privacy, project management standards, and business process models.

The first article, "Go for it: Where IS researchers aren't researching", is authored by Carol Saunders and Anne-F. Rutkowski. This viewpoint article describes two research topics under-researched by Information Systems (IS) researchers: Robotics and Information Technology (IT) addiction. These topics offer great potential for IS researchers in terms of business and societal impacts, and it would behoove IS researchers to study them more fully. The aspects of the research topics that are related to IS are discussed, and potential research areas and questions are suggested.

The title of the second article is "Consumer perspectives on information privacy following the implementation of the GDPR", which is authored by Wanda Presthus and Hanne Sørum. The General Data Protection Regulation (GDPR) aims to strengthen consumers' rights to data privacy. This paper investigates to what extent consumers are concerned about information privacy issues following the implementation of the GDPR in the European Union. The authors present findings from an online survey conducted during spring 2019 among 327 Norwegian consumers, as well as findings from a survey, conducted immediately prior to the implementation of the GDPR in spring 2018. Some main conclusions from the study are: (1) consumers gained significant knowledge about their information privacy from the GDPR, but felt relatively little need to execute their enhanced rights; (2) about 50% of respondents believed themselves to have control over their data, while almost 40% stated that they had no control about their personal data; and (3) consumers largely trusted companies to manage their personal data. These insights are of interest to both academia and to industries that deal with personal data.

The third article, authored by Nathalie Perrier, Salah-Eddine Benbrahim, and Robert Pellerin, is entitled "A comparison of project control standards based on network analysis". Project control is a crucial function in project management. Over the years, several best practice standards have been developed to assist project managers in improving project control. The objective of this paper is to compare three prominent best practice models of PMBOK, PRINCE2, and the AACE framework concerning to the core processes of project control. Network analysis is used to achieve this objective. The results show that influential and linkage processes, such as Control quality, Review stage status, Forecasting, and Change management, have the most significant impacts on the complexity of the project control function. This work has the potential to help rethink the project control function by creating a more global view of the most central and critical processes for project control, from which enhancement in the ability to control the project can be drawn.

"Business process models and entity life cycles" is the fourth article and is authored by Giorgio Bruno. As the author states, tasks and business entities are the major constituents of business processes, but they are not always considered equally important. The activity-centric approach and the artifact-oriented one have radically different visions. The former focuses on the control flow, i.e., on the representation of the precedence constraints between tasks, and considers the dataflow an add-on. The latter emphasizes the states of the business entities and defines the transitions between states in a declarative way that makes it difficult to figure out what the control flow is. This paper presents the ELBA notation, whose purpose is to integrate those different visions by leveraging the dataflow. The dataflow defines the input and output entities of the tasks in process models. Entities flowing through tasks change their states, and then a

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process model results from the combination of the life cycles of the entities managed by the process. Process models are complemented by information models that show the attributes and relationships of the entity types handled by the processes. Life cycles are intertwined in process models, but they can be separated through an extraction technique that is illustrated in this paper with the help of two examples.

We would like to take this opportunity to express our gratitude to the distinguished members of the Editorial Board, for their commitment and for sharing their knowledge and experience in supporting the IJISPM.

Finally, we would like to express our gratitude to all the authors who submitted their work, for their insightful visions and valuable contributions.

We hope that you, the readers, find the International Journal of Information Systems and Project Management an interesting and valuable source of information for your continued work.

The Editor-in-Chief,

João Varajão

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João Varajão is currently a professor of information systems and project management at the *University of Minho*. He is also a researcher at the *ALGORITMI Research Center* at the *University of Minho*. Born and raised in Portugal, he attended the *University of Minho*, earning his Undergraduate (1995), Masters (1997), and Doctorate (2003) degrees in Technologies and Information Systems. In 2012, he received his Habilitation degree from the *University of Trás-os-Montes e Alto Douro*. His current main research interests are related to Information Systems and Information Systems Project Management success. Before joining academia, he worked as an IT/IS consultant, project manager, information systems analyst and software developer, for private companies and public institutions. He has supervised more than 100 Masters and Doctoral dissertations in the Information Systems field. He has published over 300 works, including refereed publications, authored books, edited books, as well as book chapters and communications at international conferences. He serves as editor-in-chief, associate editor and member of the editorial board for international journals and has served on numerous committees of international conferences and workshops. He is the co-founder of CENTERIS – Conference on ENTERprise Information Systems and of ProjMAN – International Conference on Project MANagement.

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Go for it: Where IS researchers aren't researching

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Go for it: Where IS researchers aren't researching

Viewpoint

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Abstract:
This viewpoint article describes two research topics under-researched by Information Systems (IS) researchers: Robotics and IT addiction. These topics offer great potential for IS researchers in terms of business and societal impacts and it would behoove IS researchers to study them more fully. The aspects of the research topics that are related to IS are discussed and potential research areas and questions are suggested.

Keywords:
robotic technology; robots; IT addiction; dark side of IT; research areas.

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1. Introduction

In the first decade of the new millennium, there was a big debate about what Information Systems (IS) discipline is and is not. Many IS researchers provided their two cents about an identity crisis in the IS discipline, the most notable of which were the comments by Benbasat and Zmud [1] and Agarwal and Lucas [2]. Relatedly, there were attempts to identify the IS intellectual core by Sidorova, Evangelopoulos, Valacich and Ramakrishnan [3], as well as others in a Special Issue of the Communications of the Association for IS in 2003.

Concomitantly an exciting new era of research about electronic commerce was revving up. Our view is that the IS discipline was slow to enter the conversation about electronic commerce (e-commerce). Maybe it was because many IS researchers thought that research in this area was outside the IS core. Maybe it was because the IS journals were too demanding about requiring rigorous methodology and strong theory in the research on this still emerging phenomenon. Whatever the reason, while IS journals considered the merits of research on e-commerce, the marketing researchers, never shy, rushed in and gained a strong foothold on the market for e-commerce research. IS researchers eventually joined the party, but it was after marketing departments were offering courses and marketing researchers were publishing research to understand this new phenomenon.

Another example of attempting to limit the reach of IS research was experienced by one of the authors when she served as Senior Editor on a gamification paper [4]. Members of the review team voiced their concern that the topic, gamification, was not appropriate for MISQ when the manuscript was first submitted around 2010. However, it is now clear that gamification is not only important to millennials, but also to companies like Uber and UPS that are using it to control their workers [5]. Further, it is clear that gamification is a legitimate topic for IS researchers.

We believe that the IS discipline can play an even more important role in the current digital era that is ripe with new technologies and innovations. IS researchers have recognized the huge potential societal and business impact that big data, business analytics, Artificial Intelligence (AI) and machine learning offer, and they are actively engaging in research on these topics - research topics that are being explored concomitantly in other disciplines such as marketing and management. Almost weekly there are calls for papers for Special Issues in IS journals on these topics and related tracks are popping up in major and boutique conferences alike.

Ironically there are several research topics with rich potential that are not being widely addressed by IS researchers. We would like to bring two of them to your attention: robotics and IT addiction. With a few exceptions that we note below, we have not seen these topics published in IS journals. Further, with the exception of HICSS which has a minitrack on Machine Learning, Robotic and Toy Computing and ICIS which has a Human Computer/Robot Interactions and Interfaces track and mentions it as a topic in the Human Behavior and IS track, we have not seen specific tracks or minitracks for either Robotics or IT addiction at major IS conferences. We would like to draw on our recent book, Emotional and Cognitive Overload: The Darkside of Information Technology, by describing why these two topics might be of interest to IS researchers and outlining potential research areas. When it comes to doing research on these topics, we would like to encourage IS researchers: Go for it!

2. Robotics

Robots are hardly a new thing. The first one was developed by Archytas of Tarentum in the third century. It was a steam-powered mechanical bird called "Pigeon." In 1495, Leonardo da Vinci created a robot from a knight's suit of armor and an internal cable mechanism. It was not until the 20th century, though, when they were installed into assembly lines, mostly automobile assembly lines, that robots became more commonplace.

By robot we mean "a reprogrammable, multifunctional manipulator designed to move material, parts, tools or, or specialized devices through variable programmed motions for the performance of a tasks" [6, p. 70]. The term 'robot' was derived from the Austro-Hungarian empire term, robota, which means "vassal" or "worker" and first appeared in Capek's 1921 play Rossum's Universal Robots, or R.U.R. [7].

GM first put a robot (i.e., George Devol's industrial robotic arm) to work on its assembly line in 1961. GM's first robots were used for die casting, welding, and painting operations. Twenty years later, 300 robots were working on GM's factory floor [6]. Now the number of robots working at GM has mushroomed to over 30,000 [8]. Other car companies have followed GM's lead by placing robots on their assembly lines. Recently, the industries showing the greatest growth in robot density are transportation equipment, metal industries and chemicals [9]. The science of robotics was initiated in 1959 in MIT's Artificial Intelligence Laboratory by John McCarthy and Marvin Minsky on one coast and at Stanford University on the other coast. A little later, business organizations also were conducting their own robotics research. Because of this research, today's robots boast anthropomorphic cognitive capabilities which are based on AI. Further, their physical form is designed to match the function(s) they perform - and do so reliably, predictably and safely [7]. Increasingly robots are becoming valued members of industrial teams as they work alongside humans (e.g., as cobots).

2.1 Reasons for Using Robots

Industrial robots are used increasingly because they perform the work accurately, efficiently and at ever-lower costs. They are especially useful in performing tasks that are "dangerous, dirty, or dull". They can lift and move heavy objects reliably and repeatedly with an accuracy that is within a small fraction of a millimeter [10]. They can perform numerous warehouse functions. For example, Amazon uses an army of over 100,000 robotic systems in its 25 fulfilment centers around the globe. Its varied robotic systems are designed to perform a range of tasks including transporting packages, sorting packages by booting them into desired chutes, handling pallets, and working with human employees who pick and stow the packages. Amazon claims that its use of robots has helped it store an additional 40 percent of inventory in its fulfilment centers [11]. Southern Glazer's Wine and Spirits LLC, the largest alcoholic-beverage distributor in North America, uses robots to support order routing, pallet and case conveyor systems, and voice directed picking in its Leesburg, Florida plant. Its highly automated system allows it to process a remarkable 12,000 cases an hour [12]. Robots also can be found cheering up the elderly in Japanese retirement homes, performing minimally-invasive laparoscopic surgery, checking the quality of welds, detonating bombs, driving cars, delivering anesthesia (by a robotic system called McSleepy), giving priestly blessings (by a robotic system called BlessU-2), and working on the International Space Station [10; 13; 14; 15]. Increasingly they can be used to perform tasks that are non-routine and have cognitive and emotional, as well as physical, components [13].

It is likely that the use of robots will increase as their price plummets. Over the last 30 years, the price tag for a typical robot has halved both in real terms and in relation to labor costs [9; 16]. Graetz and Michaels [9] estimate that increased use of robots contributed to annual labor productivity growth and total factor productivity, though at diminished marginal gains. Further, the efficiencies, increased storage, labor savings, and other operational improvements that their use stimulates makes robots even more appealing in industry. For example, a recent New York Times article about Dynamics, a manufacturer of molds for the mass production of small plastic and metal parts, notes: "The robot's price tag was $35,000, and within two months, it paid for itself by quadrupling the efficiency of the press and eliminating scrap" [8, p. 32].

Robots are perceived as an efficient way to alleviate or avoid human errors. Indeed, the operating system of humans (i.e., brain) is delivered at birth full of defects (e.g., with cognitive biases and emotion). The actual trend is therefore to introduce smarter systems and more software to empower robots' actions. Indeed, scientists are working on developing "evolved" robots with human traits, emotions, and intentions that can be trusted. The increased use of robots may lead to more varied, often more creative and highly skilled, jobs with reduced day-to-day drudgery. The end result is that people may have more time to enjoy their lives (e.g., [13; 17]).

2.2 On the Dark Side of Robotic Technology

There are several dark sides of Robotic Technology: Safety, dangers resulting from their incorrect use, and negative impacts of their use on human workers. Safety is the oldest known dark side of robot technology in manufacturing organizations. Robots started working in Japanese companies in 1969 and they became increasingly important in industry as the number of Japanese companies using them nearly doubled each year from 1975 and 1981 [6]. Unfortunately, the number of safety issues associated with their use also grew. In 1983, the Japanese Ministry of Labor reported 48 recorded accidents involving human workers and robots, which represents a high fatality ratio when compared to most common occupational situations. Further, robots have been credited with causing deaths when humans got too close to them [10].

To enhance robotic safety, Hamilton and Hancock [6] recommended proximity sensing systems and exclusion mechanisms. Proximity sensing systems are designed to prevent robots from coming in contact with humans. Exclusion mechanisms reduce the likelihood of humans being harmed by preventing them from entering locations where robots are operating. Amazon has put fencing around the robots in its fulfilment centers to keep its employees safe, as well as to improve the efficiency of its operations [11]. Amazon also equips its employees with a bright orange Robotic Safety Vest with embedded sensors. The robots can detect when a human is nearby and either slow down or stop entirely depending on the employee's proximity (ibid). In another example, the owner of Dynamics (the mold manufacturer mentioned above) subjected himself to a collision with a robot in his plant to estimate the potential harm to employees. The robot was purchased and installed only after passing the owner's safety test [8].

The misuse of robotic technology can also constitute a dark side - one that can lead to death. The Da Vinci robot, a minimally invasive robotic surgery system, has many merits: It facilitates greater precision in surgical incisions and it offers superior views of the patient's surgery site, especially because there is less blood to obscure the vision. On the dark side, innovative robotic technologies have been blamed for patients' deaths in recent years [18]. Probably the most publicized was the death of a Chicago man in 2007. Unfortunately, a surgeon punctured the patient's spleen when operating a $1.8 million Da Vinci "hands-on" robot surgical robotic system for the first time on a living person.

A Saunders, Rutkowski, Pluyter & Spanjers [19] article published in the interdisciplinary journal, Journal of the Association for Information Science and Technology, suggests five hazards that are prevalent in such tragedies: (i) overloaded or underloaded Operating Room (OR) professionals, (ii) inadequate surgeon training on the robotic systems, (iii) inadequate training for the healthcare professionals on the surgical team, (iv) the complexity of Health Information Technologies (HITs), and (v) overconfident surgeons. To avoid these hazards, they argue for adequate training of healthcare professionals accompanied by a certification of mastery of use of the technology upon completion of the training. Since surgical robots are not fully automated, their use depends on how well a surgeon is trained in operating with them. Surgeons need to learn how to make sense of the clear and detailed 3D images the systems provide, and to employ the semi-automated robot as an extension of their human body. That is, the surgeon's performance depends on the control of the robotic system using the haptic (force and tactile) feedback received from the system while they are operating. In the context of the OR, not only the surgeons, but also the whole team has to be trained to cope with adverse events. Publications in the medical field report on the potential of realistic Crew Resource Management programs to train surgeons and medical teams in dealing with distractions [20]. Also commonly used in the military and aviation industries, CRM programs are simulation-based and provide training for technical skills, as well as non-technical skills such as communication and teamwork.

A good example of robotics research is a recent study by Sergeeva, Huysman and Faraj [21]. Sergeeva and colleagues spent over 100 hours observing the challenges surgeons and surgical teams face when learning to operate the Da Vinci robotic system. In one OR emergency situation, Sergeeva et al. observed the anesthesiologist crawling under the table upon which the patient was resting in order to reinsert a breathing tube that had fallen out of the patient's mouth. Their research, like ours, suggests that operating, or co-operating, with the robotic systems can be dangerous and the entire team needs to be trained to provide coordinated responses to unanticipated problems. It is important to realize that robots can be operated by humans, but are mostly led by software.

Self-driving cars are distant from our classical anthropomorphic vision of robots. However, they drive and make decisions using operating systems similar to those used by automated pilots in planes and by many robots. The software and AI become the mind of the non-human entity. As reported in IEEE software journals, software is not free of defects and good software development practices are lacking. This can be lethal for airplane (Boeing 737 Max) or self-driving vehicle (Tesla) passengers. For example, software misinterpreting external inputs such as distinguishing a large white 18-wheel truck and trailer crossing the highway against a bright spring sky is a deadly example of recurrent issue in safety-critical system failures [22].

While some argue that robots are net job creators, others are concerned that they will be net destroyers of jobs. When canvassed in a survey, the split was pretty even across respondents holding these two positions - though respondents voted slightly in favor of a net gain in jobs (52%) versus a net loss in jobs (48%) [17]. Those concerned about a net loss stated that the trend toward replacing workers with robots to generate labor saving, and gains in efficiency will only accelerate. While white collar jobs may be affected, the biggest impact will be on blue- and pink-collar jobs. For example, Southern Glazer's Wine and Spirits LLC plans to ultimately replace the blue-collar workers in its Leesburg distribution center with robots [12]. As a result, on a societal scale there will be greater inequalities between highly skilled workers and others, as well as the deskilling of many jobs. The consequences may yield a permanent underclass [17].

2.3 Possible Research Areas on Robotic Technology

The IS discipline has demonstrated interdisciplinary expertise across a broad range of research areas. Working in teams, human-computer interactions, design of safety-critical systems, IS economics, technological innovation, and ethics related to technology are just a few. We can apply this expertise to research on robotic technology.

Our decades-long research on group support systems and virtual teams might help answer questions like these: How can industrial teams effectively incorporate robotic technology into their operations on the plant floor? How can humans learn to trust their 'cobots'? How does the presence of 'cobots' affect communications of human members of industrial teams? How can we train surgical teams to work more effectively with medical robotics systems?

IS research on human-computer interactions and the design of safety-critical systems could inform the design of robots. In particular, it could provide insights about how robots could be designed to best accomplish a specified function, what design can best enhance human-robot interaction or how robots should be designed as safety-critical systems. What level of control do we want to give to robots? What are the legal and economic consequences of malfunctioning robots causing harm for a company or a user? How much emotion should a robot be equipped with? Who should control the robot?

Further, research on technological innovation and IS economics could provide insights about how organizations should go about deciding whether or not to adopt robotic systems (especially given the cost of cheap labor), how to implement them successfully, and which challenges to anticipate during the implementation. Research also could address how we should rethink the concept of work or how can our public institutions (especially educational institutions) be prepared for the wave of change due to robotics? What role does bounded automation [13] play in the use of robots? What are the economic consequences of work substitution?

An area that IS researchers are starting to explore more fully is that of ethical issues. The use of robotic systems offers an opportunity for venturing even further in these explorations. The use of a cuddly small seal-like robot called PARO to console elderly Japanese residents of nursing homes even offers some possibilities for study. Ethicist and philosophy professor Sharon Vallor has raised an ethical issue about PARO replacing caregivers: "My question is what happens to us, what happens to our moral character and our virtues in a world where we increasingly have more and more opportunities to transfer our responsibilities for caring for others, to robots?" [23, p. 124]. Ethical issues related to robots are more obvious in the case when the driver in a self-driving Tesla was killed [24]. Should the robot be blamed? Will robots have legal rights? Since the self-driving Tesla is not 'human,' it is more likely that the car company or the software developers will be blamed. Even more nuanced ethical decisions might need to be reflected in software design. As Rutkowski and Saunders [23, p. 124] note: "If a human is in command, he will be blamed for making the wrong

decision. If the robot is in command, the software developer likely will be blamed. Some believe that having the most perfect algorithms is always superior to human information processing; Others say that it is just about enforcing more legal regulations on developers." Still another aspect of ethics as it relates to robotics systems focuses on the marginalization of workers replaced by the technology. Who, if anyone, should be responsible for training them or otherwise finding a viable place for them in our society? What mechanisms (i.e., workers' councils, unions) can help protect the workers in the face of robotic technology? Clearly there are a lot of ethical issues for IS researchers to explore.

3. IT Addiction[1]

Another topic that is under-researched by IS researchers is IT addiction. The term "addiction" has a negative connotation. It is commonly related to substance abuse impacting brain functions and, therefore, behaviors. Mainstream psychology and mental health journals primarily view addiction through the neurophysiological lens of the Brain Reward System (BRS). The BRS is a complex cerebral circuit engaging specific neuronal pathways that are modulated by cortical oversight systems affiliated with emotion, memory, judgment and decision making. The BRS is extremely responsive to positive and negative reinforcements, which helps explain the phenomena of addiction in both animals and humans [25]. By IT addiction we mean "the state of being challenged in balancing IT usage mindfully so as to preserve one's resources [and] includes Internet, mobile email, and SNS addictions" [23, 137]. Consequently, IT addiction is mostly associated with excessive Internet sessions (i.e., abuse) and the experience of distress when mobile phone connectivity is lost (i.e., the emotional and behavioral consequences). However, IT addiction is currently not one of the mental disorders listed in the latest Diagnostic and Statistical Manual of Mental Disorders (DSM-V). Most psychiatrists and psychologists believe that a common set of symptoms and diagnosis criteria are missing to include it [26]. However, most converge on the idea that the lack of control consciously exerted by the brain on its reward system contributes heavily to IT addiction [27].

3.1 Only a Dark Side for IT Addiction

All generations are staying connected too long on Internet and Communication Technologies (ICT), which is causing a range of dysfunctional behaviors. These behaviors, which are related to IT addiction, are often turned into buzz words or acronyms such as FOMO (Fear Of Missing Out), iDisorder, or more recently Nomophobia (No-Mobil-Phone-Phobia) in the popular press. Nowadays, "being FOMO " or declaring oneself as a "nomophobe" is "voghish", not to say socially desirable. Some acronyms have been scientifically addressed; others have not been fully addressed yet. For example, Fear Of Missing Out (FOMO) is defined as "a form of social anxiety—a compulsive concern that one might miss an opportunity for social interaction, a novel experience, or some other satisfying event aroused by posts seen on social media sites" [28, p. 69]. Nomophobia[2] relates to the phobia of being out of cellular phone contact, but has no standardized definition yet. Before these fashionable acronyms flourished on the web, scientific research has found that 58 per cent of adults and 68 per cent of young adults checked their phones more than once an hour; 73 per cent panicked when they misplaced devices; 14 percent felt desperate and 7 per cent became physically sick when their smartphone went missing [29]. Two decades ago, Kandell [30, p.11] characterized psychological dependence on the Internet as: "(a) an increasing investment of resources on Internet-related activities; (b) unpleasant feelings (e.g., anxiety, depression, emptiness) when offline; (c) an increasing tolerance to the effects of being online; and (d) denial of the problematic behaviors." Also, research demonstrates that excessive smartphones usage can lead to unreasonable preoccupation with the device as well as frustration and anger when interrupted [26]; It also can lead to Attention Deficit Hyperactivity Disorder (ADHD), depression, and social phobia in millennials [31]. In summary, users across generations find it hard to unplug, and they suffer serious consequences as a result.

[1] For a more detailed discussion of the BRS and IT addiction, please see our book "Emotional and Cognitive Overload: The Dark Side of Information Technology".

[2] https://en.wikipedia.org/wiki/Nomophobia (downloaded 5/25/2019).

The early work of Davis [27] is particularly relevant in understanding phenomena such as FOMO, nomophobia or internet bulimia. Davis proposed a cognitive-behavioral approach to IT addiction which he defined as Pathological Internet Use (PIU). PIU is defined as the negative consequences of problematic cognition coupled with behavior that intensifies or maintains maladaptive responses [27]. Davis [27] identified two distinct forms of PIU: specific (i.e., overuse or abuse of content specific functions of the Internet as an underlying element of broader behavioral disorders) and generalized (i.e., a multidimensional pathological overuse of the Internet itself due to the unique communicative context of the Internet). Overall, PIU behaviors are considered specific when an individual is predisposed to develop maladaptive usage through a pre-existing pathology and becomes dependent on a particular Internet function such as online auction services, sexual material/services, or gambling. PIU is considered general when the Internet is overused such as when people spend time online because they are bored or feeling lonely (see [32]), or when they develop problems due to the interpersonal contexts available online (see Caplan [33; 34; 35]). This multidimensional pathological overuse/misuse can result in deleterious personal and professional consequences. But whether it is called IT addiction, Internet addiction, FOMO, nomophobia or PIU, it is a force to be dealt with in our society.

3.2 Possible Research Areas and Measures Related to IT Addiction

Most studies of IT addiction have been conducted using a behaviorist perspective. It may be worthwhile to adopt a cognitivist-emotional perspective, as well as to employ neurophysiological tools, to study, for example, BRS in conjunction with general PIU (i.e., see [36]). Notably, neurohormones such as dopamine and oxytocin (the 'love hormone') are heavily involved in activating BRS mechanisms. Brain activation and a focus on attachments are surely interesting constructs when considering the abuse of social media such as Facebook or Instagram. Nomophobia and FOMO may be modern forms of Not to Be Missed Phobia (No2BMphobia) or Fear to Be Alone (F2BA), rather than a love of smartphones or connectivity. These phenomena are not to be confused with one another and warrant more research. Some possible research questions include: What causes over-connectivity on smartphones? As a result of Social Network Systems (SNS) technology's primary function to link us to loved ones, does the brain become inundated with oxytocin and, consequently, is general PIU likely to occur? To what extent does continued use of social media reinforce BRS and create situations of general PIU? To what extent do SNS extrinsic rewards such as status, number of likes, and positive comments lead to difficulties in disconnecting from Facebook? How is specific PIU related to serious underlying elements of mental disorders and personality disorders (e.g., narcissist personality disorder, social phobia)? How can SNS and mobile phone technologies be designed to reduce IT addiction? What types of alerts can be created to warn of the imminent possibility of IT addiction?

Answering these questions will require a multi-disciplinary approach involving mental health specialists (e.,g. psychiatrists, psychologists) and possibly neuroIS scientists to interpret fMRIs showing what portion of the brain is activated when dysfunctional behaviors are displayed. Our field has always been interdisciplinary and willing to work across multiple disciplines. For this reason, IS researchers are in an excellent position to initiate the multi-disciplinary research needed to answer the questions raised above.

Finally, the time spent on the Internet or being connected is not in itself a symptom of addiction [29; 37] or PIU [38], but rather its precursor. In the past, measuring actual usage time online or on the device has proven problematic, and most research fails to reflect accurately users' task-switching/multitasking behaviors. Research has demonstrated that measures of usage relying on the self-reported hours and minutes users estimated that they had accessed Facebook, Twitter, and their e-mail differed significantly from the actual time monitored with software installed on their computers [37]. For example, while users self-reported spending an average of 149 min per day accessing Facebook on their computer, the actual average time, according to the monitoring software, was 26 minutes per day. To properly assess IT usage and its impact on IT addiction, new measurement scales must be developed and validated (see the Media and Technology Usage and Attitudes Scale by Rosen et al. [29]). Further, self-reported data can be complemented with physiological markers collected through a range of sensors available on simple devices such as watches or armbands (e.g., SenseWear Pro 3 armband). A new challenge is to design methodological tools to capture a more complete, holistic and conceptual portrayal of IT addiction and its precursors (i.e., triangulation).

4. Conclusion

There is clearly some interesting research being conducted on Robotics and IT Addiction. However, that research is not being published in Information Systems Journals and, for the most part, it is not being conducted by IS researchers. Why not? The phenomena clearly have huge potential impact on individuals, industry and society. Studies of these phenomena could benefit from the expertise and involvement of IS researchers. It appears that these topics may offer a golden opportunity for IS researchers. We urge them: Go for it!

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Consumer perspectives on information privacy following the implementation of the GDPR

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Abstract:
The General Data Protection Regulation (GDPR) was implemented in the European Union and European Economic Area in May 2018. The GDPR aims to strengthen consumers' rights to data privacy in the wake of technological developments like big data and artificial intelligence. This was a hot topic for stakeholders, such as lawyers, companies and consumers, prior to the GDPR's implementation. This paper investigates to what extent consumers are concerned about information privacy issues following the implementation of the GDPR. We present findings from an online survey conducted during spring 2019 among 327 Norwegian consumers, as well as findings from a survey conducted immediately prior to the implementation of the GDPR in spring 2018. We draw the following conclusions: (1) consumers gained significant knowledge about their information privacy from the GDPR, but felt relatively little need to execute their enhanced rights; (2) about 50% of respondents believed themselves to have control over their data, while almost 40% stated that they had no control about their personal data; and (3) consumers largely trusted companies to manage their personal data. These insights are of interest to both academia and to industries that deal with personal data.

Keywords:
information privacy; General Data Protection Regulation; GDPR; consumers; online survey.

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1. Introduction

The aim of this paper is to study information privacy from a consumer perspective following the European Union's (EU's) implementation of the General Data Protection Regulation (GDPR). Information privacy has sparked academic interest since Warren and Brandeis's seminal paper in 1890, which defined 'privacy' as 'the right to be left alone' [1 p. 994]. Numerous studies since then have investigated privacy, as well as the subcategory 'information privacy', which focuses on an individual's control over their personal data. Overall, these studies have produced a number of frameworks, models and taxonomies, such as the PAPA framework [2], the privacy calculus model [3] and Solove's taxonomy of privacy [4]. Research has also shown that consumers do not seem to be particularly concerned about their privacy [5, 6] and that the reasons for this vary, from lack of consumer understanding of the concept [4], to a conscious, calculated decision to give up personal data in exchange for benefits [3] to confusion or resignation [7]. *"In 1999, the CEO of Sun Microsystems® proclaimed that 'You have zero privacy anyway…get over it'*. More recently, Mark Zuckerberg of Facebook similarly declared that *'The age of privacy is over.'* [7 p. 64]. However, others clearly advise individuals to protect their privacy and not to surrender it without notice or choice: *'We can and must resist'* [7]. Against this background, consumers gained legal protections for their information privacy when the GDPR was implemented on May 25th, 2018.

While the GDPR is at heart a legal policy, it also affects other fields, such as information systems. For example, companies must comply with the GDPR by securing customer data, informing visitors to their websites about their rights and altering their information systems so that customers can understand, change or even delete certain personal data [8, 9]. A company's failure to comply can result in high fines and a loss of reputation. After the implementation of GDPR, Google's French operation was the first company to be sued for lack of transparency and unclear user consent conditions, when the French Data Protection Authority sued Google for 50 million Euros [10]. Similarly, the Norwegian Data Protection Authority sent the Directorate of Norwegian Customs a warning for a fine for nearly 100,000 Euros for its collection and management of customer data from surveillance cameras without appropriate consumer consent, in a case concerning 80 million records of traffic movements in which it was possible to identify the drivers' faces [11].

Shortly prior to the implementation of the GDPR, we conducted a survey (n = 216) revealing that consumers were somewhat or highly aware of the impending GDPR but were only somewhat concerned with their privacy in general [6]. The present paper follows up on those findings and seeks to discover to what extent consumers are concerned about information privacy issues following the implementation of GDPR. This paper draws on a survey (n = 327) conducted among Norwegian consumers during spring 2019, nearly a year after the implementation of the GDPR.

The rest of this paper has the following structure: first, we present related work on information privacy and the GDPR in Section 2. Then we describe our method in Section 3, followed by our results and discussion in Sections 4 and 5, respectively. Finally, we conclude in Section 6.

2. Related work on information privacy and the GDPR

In this section we present related work on information privacy in the information systems (IS) discipline (as opposed to, for example, a philosophical, psychological, marketing or legal context [12]), followed by a brief description of GDPR.

2.1 Information privacy

Our point of departure was the extensive paper by Bélanger and Crossler [12] that conducted a literature review of information privacy within an information systems context. In our digital society, IS are highly important for the development of almost any human organisation [13] and this rapid development entails both challenges and opportunities [14]. Several papers conclude that, in our digital age, trust is highly important, especially regarding online transactions and the handling of sensitive personal information [15], since, based on an analysis of an individual's transactional data, companies can now understand and predict that individual's preferences and future behaviour. Moreover, a study by Chang et al. [16] found that perceived privacy control among online banking customers

significantly affected customers' trust and perceived privacy. At the same time, however, Obar and Oeldorf-Hirsh [17] found that 74% of people signing up for a social networking service skipped reading the privacy policy, which should have taken 29–32 minutes to read through, and spent on average less than 1 minute reading the terms of service, which should have taken 15–17 minutes to read through. This indicates that users pay little or no attention to such information and introduces what researchers call the privacy paradox [12], in which consumers claim to be concerned with their privacy but do not behave accordingly. For example, a consumer may express an intention to protect her personal data, yet will quickly disclose them in exchange for convenience when shopping online. According to Bélanger and Crossler [12], this is an important aspect of studying information privacy: *'Even if other streams of IS research suggest that intentions lead to behaviors, the privacy paradox should be explored further to provide an understanding as to why such is not the case with information privacy. Furthermore, researchers should not assume de facto that intentions lead to behaviors when information privacy research is conducted'* [12, p. 1021]. Similarly, another study on the privacy paradox found that consumers were willing to trade their privacy in exchange for perceived security benefits, convenience and efficacy [18]. Additional studies have also found this variant of the privacy paradox specifically among social media users, and have called it the 'privacy trade-off' [19]. At the same time, other research has called into question whether consumers really care if a retail store can use their data to predict things about them, for example pregnancy [20].

2.2 The GDPR

The GDPR went into effect on May 25th, 2018 in all EU and European Economic Area (EEA) countries. Technological advances like big data and artificial intelligence have made personal data abundant and ubiquitous, and it is now easy for companies to collect and analyse online consumers' behaviours and shopping habits. The aim of the GDPR is therefore to *'harmonize data privacy laws across Europe'* (https://gdpr-info.eu/) and to increase consumer rights and transparency [9]. Its 99 articles can be found in full online. The first article states that *'This Regulation lays down rules relating to the protection of natural persons with regard to the processing of personal data and rules relating to the free movement of personal data'*; in other words, consumers have enforceable rights to their personal data. Article 4 further states that *'"personal data" means any information relating to an identified or identifiable natural person ("data subject"); an identifiable natural person is one who can be identified, directly or indirectly, in particular by reference to an identifier such as a name, an identification number, location data, an online identifier…'*.

Prior to its implementation, the GDPR and privacy rights were hot topics of discussion in Norway and many companies sought to implement the requirements of the GDPR. While it is interesting to understand how the regulation affects individuals, it is also vital that companies understand and implement the GDPR's privacy requirements, and publications have sought to guide companies and provide them with practical advice and solutions [9]. Although a study on GDPR compliance in Norwegian companies found that most companies were well informed about the new regulations and rated themselves as well prepared, many were interested in addressing practical issues and challenges introduced by the regulations [8]. It seems likely that the French lawsuit against Google will be only the first of many prosecutions brought against companies for violating the GDPR. Moreover, the implementation of the GDPR presents a number of technological challenges as well as solutions. For example, a consumer may request the deletion of their data, but this may prove technologically impossible despite a company's best efforts at compliance [21, 22]. The French case against Google also illustrates how far the GDPR reaches: it affects any company that interacts with citizens of the EU or EEA, meaning that even American-based companies like Google and Facebook must follow the GDPR if they have users from the EU or EEA [23]. However, GDPR does not come without challenges. Koops has critically pointed to technological challenges as well as changing the mindset of developers [21, 22], and Mateosian has challenged the consumer with asking whether it really matters if a retail store can predict pregnancy [20]. It remains to be seen exactly what difficulties may arise from this new regulation.

In the present study, we focused on seven aspects of the GDPR, see Table 1. We selected these topics based on two criteria: first, they were emphasised by the Norwegian Data Protection Authority (https://www.datatilsynet.no/rettigheter-og-plikter/den-registrertes-rettigheter/) and by Jarbekk and Sommerfeldt [9], and second, they are specifically directed towards consumers (as opposed to organisations, for example Article 37 of the GDPR, *'Designation of the data protection officer'*).

Table 1. Our seven topics and corresponding GDPR articles

Topic	Article(s)	Notes
Right to information	5, 12, 13, 14	The individual has the right to know how companies collect and store personal data.
Right to access, change or restrict the processing of information	15, 16, 18	Consumer questions or requests for their personal data must be answered within 30 days. During this period, their data can be stored by the company but not processed.
Right to erasure	17	Right to have parts of their personal data deleted.
Right to data portability	20	Right to transfer personal data.
Right to object	21, 30, 7	Consumers must be given the chance to approve a company's online terms and conditions, acceptance of cookies and marketing.
Automated individual decision making	22	Consumers must be notified of the use of artificial intelligence and automated decision making.
Territorial scope, trade for benefits	3	Facebook, disclosing data for benefits.

3. Methods

Our data were collected during February and March 2019 via an online survey questionnaire that was developed with the software tool SurveyMonkey®. The questionnaire consisted of 17 questions, including 4 background questions, 12 primary survey questions or statements and 1 open comment field at the end of the survey (see Appendix). Respondents could also provide qualitative feedback for all of the 12 primary survey questions. The purpose of the survey was to generate insights into consumer views about information privacy and to give respondents an opportunity to share their reflections and thoughts related to the survey topics. The questionnaire included Likert-scale, multiple-choice and open-ended questions that requested qualitative answers. The questions also drew inspiration from a prior survey that we conducted in 2018 [6]. A progress bar was visible at the bottom of each survey page so that respondents could see how much work remained to complete the survey.

The survey respondents were first shown an introductory text at the beginning of the questionnaire that informed them about the survey contents. Participation was voluntary and anonymous, and participants could quit the survey at any time. The data were collected through a weblink created by SurveyMonkey®. Before the survey launched, we conducted a pilot test with three respondents and both the desktop and mobile versions of the questionnaire; the pilot test participants were not members of the research team. The pilot test resulted in a few modifications and changes to the survey: some questions were reworded for clarity and some additional answer options were included.

The final survey received 327 respondents before being closed to further participation. Since not everyone who started the survey completed it, our results report the number of respondents (*n*) for each of the findings reported in this paper. The average time to complete the survey was 6 minutes. The research team carefully reviewed and discussed all of the answers and used descriptive statistics to get an overall impression of the data. We also selected some particularly relevant questions from the survey for more detailed analysis.

3.1 Respondent profiles

Table 2 provides an overview of the survey respondents. More men (54%) participated than women (45%). Most respondents were 21–25 years old, followed by the 26–30-year-old group. The data also show that 62% of respondents had heard of the GDPR and stated that they understood the meaning of the term and the content of the regulation; 31% knew a little bit; 3% had a vague understanding and almost 5% had never heard of the GDPR.

Table 2. Respondent characteristics in percentage, with the actual number of respondents in parentheses

Characteristic	Measurement scale
Gender	Female: 44.65% (146); male: 54.43% (178); did not specify: 0.92% (3).
Age (years)	Under 18: 0% (0); 18–20: 7.03% (23); 21–25: 56.27% (184); 26–30: 17.74% (58); 31–35: 7.34% (24); 36–40: 3.98% (13); 41–50: 6.12% (20); 51–60: 0.92% (3); over 60: 0% (0); did not specify: 0.61% (2).
Occupational status	Employed: 19.27% (63); student: 80.73% (264).
Knowledge of the GDPR	'Yes, and I know what it means': 61.77% (202); 'Yes, I know a little, but not enough about what it means': 30.58% (100); 'Yes, but I do not know what it means': 3.06% (10); 'I have never heard of that': 4.59% (15).

4. Results

Section 4.1. presents the results from the survey conducted in spring 2019, following the implementation of the GDPR. Section 4.2 contains some comparison highlights from a previous study we conducted immediately prior to the implementation of GDPR in early 2018 [6].

4.1 Main results from the spring 2019 survey

Table 3 shows participants' general thoughts on information privacy. The findings are structured according to three categories: control over personal information ('control'), awareness of the new regulation ('awareness') and opinions of their enhanced rights ('enhanced rights').

Table 3. General thoughts on privacy and the GDPR

Key word	Question	Answer alternatives
Control (n = 327)	To what extent do you find that your personal information exists in places that you do not have control over? (E.g., information stored in databases of different businesses)	I have control over everything: 0.92% (3) I have a lot of control: 8.87% (29) I have partial control: 46.79% (153) I have no control at all: 38.53% (126) I do not care about it: 4.89% (16)
Awareness (n = 327)	On July 20, 2018, the GDPR (General Data Protection Regulation) was introduced in Norway. Have you heard about it? (before you started answering this survey)	Yes, and I know what that means: 61.77% (202) Yes, I know a little, but not enough about what it means: 30.58% (100) Yes, but I didn't know what that meant: 3.06% (10) I had never heard of that: 4.59% (15)
Enhanced rights (n = 327)	The GDPR means that individuals have gained new rights regarding the collection and storage of personal data. What do you think about that?	I think my rights have improved: 59.81% (192) I don't think my rights have improved: 19.63% (63) I don't care at all: 3.74% (12) Do not know: 16.82% (54)

We then asked respondents to go into more detail about their enhanced rights; these results are shown in Table 4.

Table 4. Enhanced data rights under the GDPR

		Answer alternatives				
Key word	**Statement/question**	I have executed this right	I might execute this right	I will most likely not execute this right	I do not care	I do not know
Access and rectification (*n* = 321)	The GDPR gives you the right to receive a reply within 30 days when you approach businesses with questions related to your data. The overview should be sent in a readable format and you can correct any errors. What do you think about this?	7.17% (23)	59.81% (192)	22.74% (73)	2.18% (7)	8.10% (26)
Erasure (*n* = 321)	The GDPR has given you a greater right to demand that some personal information (that companies have collected) about you will be deleted. What do you think about this?	14.95% (48)	66.98% (215)	12.77% (41)	1.56% (5)	3.74% (12)
Objection (*n* = 327)	You have the right to object to companies sending you direct marketing (in the form of personal customised advertising).	32.11% (105)	36.09% (118)	22.32% (73)	3.67% (12)	5.81% (19)
Data portability (*n* = 321)	Data portability is a key part of the GDPR. This means that you can transfer all your data that one business has saved. You can require existing business to send your data to, for example, a competitor business. What do you think about this?	6.54% (21)	40.81% (131)	36.45% (117)	4.36 % (14)	11.84% (38)

Table 5 displays our findings regarding transparency, territorial scope and trade for benefits.

Table 5. Transparency, territorial scope and trade for benefits

Key word	**Question**	**Answer alternatives**
Cookies (*n* = 321)	The GDPR says that you can choose to accept some cookies, but not all, when you visit a website. In addition, the purpose of the data stored about you should be more disclosed. What do you think about this? (Check all appropriate options)	Companies have become much better at informing website visitors about cookies: 46.73% (150) Companies allow me to opt out of some cookies: 21.18% (68) I am unsure what companies actually do when it comes to cookies: 27.10% (87) I do not care: 4.67% (15) Do not know what cookies are: 0.31% (1)
Terms and conditions (*n* = 314)	When you download an app on your cell phone or install a programme on your laptop, you must approve the terms and condition. What is your typical reaction?	I read the whole text, even though it takes a long time: 0.96% (3) I quickly scroll through the entire text, but do not read everything: 16.56% (52) I click on "I agree/accept" without looking at the text at all: 62.10% (195) It depends on how much time I have or depends on the app/programme in question: It depends from time to time (depending on the app/programme in question: 20.38% (64)
Artificial Intelligence (*n* = 315)	Artificial intelligence makes it increasingly possible for companies to make automated decisions without the involvement of a human. I think it's okay that a machine algorithm performs and calculates the following: (check all appropriate options)	Whether or not I get a mortgage: 27.30% (86) The price of my insurance: 49.52% (156) How much I will receive in student loans: 49.52% (156) My examination assessments and determinations of my grades at school: 13.97% (44) What movies I should watch on Netflix (or similar services): 83.49% (263) What products have been purchased by others who also bought an item I bought on Amazon (or similar online store): 72.70% (229) Whether I am entitled to compensation if I am stripped of an asset: 24.76% (78)
Facebook, trade-off (*n* = 313)	The GDPR also affects companies outside the EU/EEA. What do you think about Facebook being affected in the ways mentioned in the other questions (for example, the right to access, rectification and deletion of data)?	I think it is great that Facebook is affected by the GDPR: 85.30% (267) I find it unfortunate that Facebook is affected by the GDPR: 2.88% (9) I do not care at all: 3.83% (12) I do not know: 7.99% (25)

4.2 Main results from the of pre-GDPR survey

We conducted a similar survey (n = 216) in early 2018, right before the implementation of the GDPR [6]. The questions differed somewhat from the post-implementation survey since we addressed comments from some participants of the first survey—namely, that they wanted a more in-depth survey and that some of our answer options were too leading. Table 6 shows the main findings from this survey.

Table 6. Main findings from the pre-GDPR survey [6]

Key word	Question	Selected answer options
Knowledge of GDPR	Have you heard about the GDPR?	Yes, and I know what it means: 46.76% (101); Yes, I know a little, but not enough about what it means: 26.39% (57)
Attitude	Implementation of the GDPR means that your information privacy rights will be enforced. What do you think about that?	It sounds very good: 64.04% (130); It sounds very good, but I do not think that it will make any difference for me as consumer: 31.03% (63)
Enhanced rights	Data portability Erasure Insight (within 30 days from companies) Agree to some cookies, but not all Terms and conditions	This is something I might execute: 53.20% (108) This is something I might execute: 48.28% (98) This is something I might execute: 52.22% (106) It sounds very good: 63.05% (128) I click on "I agree/accept" without looking at the text at all: 70.98 (137)
Artificial intelligence	I think it is acceptable that an algorithm automatically decides:	Which movies I should watch on Netflix: 80.41% (156)
Territorial scope	What are your thoughts about Facebook being affected by the GDPR?	I really hope so, because Facebook has no respect for privacy: 69.09% (114)
Trade for benefits	Which data are you willing to give up in exchange for better services or discounts?	Top three: First name: 92.02% (173); family name: 75.00% (141); e-mail address: 88.30% (166)

Overall, we found that (1) most consumers were moderately or very aware of the GDPR and of their rights in this regard but that they were sceptical of how the new regulations would be handled by organisations; (2) there were variations among the consumers in how they perceived the collection and storage of personal data, depending on the nature of the data in question; and (3) the consumers indicated relatively high concern for their privacy.

5. Discussion

In this section we discuss our findings against existing research as presented in section 2. We have arranged the discussion according to the seven topics as presented in Table 1.

5.1 Right to information

Our findings from our post-GDPR survey indicate that 56% of respondents had a moderate interest in information privacy, while 31% indicated a stronger interest; this suggests that most consumers care about this topic. These results are nearly the same as those from the survey conducted shortly prior to implementation of the GDPR [6].

We received 30 comments about this question on the post-GDPR survey, many of them thorough. These indicated a variety of responses, ranging from anxiety about information privacy to feelings of trust and not feeling threatened. Some prior research has argued that consumers lack an understanding of privacy as a concept and what it comprises; consumers are quick to exclaim *'This violates my privacy'* ([4] p. 480) and leave it at that. Addressing this problem, Solove created a taxonomy with four categories: (1) information collection, (2) information processing, (3) information dissemination, and (4) invasion. Each of these contains harmful activities such as surveillance, identification, blackmail, decisional interference and more. We agree that the average consumer lacks knowledge about technological advances. There are many algorithms and technologies at play when a consumer goes into a store or browses the Internet, including surveillance cameras, the ability to trace an individual through their smartphone, websites that harvest cookies

and web beacons [24]. Most of our participants were relatively young (56% were between 21 and 25 years old) and relatively well educated (76% held a bachelor's degree), and should therefore be accustomed to using smartphones, the Internet and other advanced technology; yet they did not seem to reflect much about their potential risks. A few responses, however, suggested that consumer interest in these topics may be increasing: *'Maybe I have too much trust'* and *'My concern is medium, but it is INCREASING'*. Unfortunately, our survey could not determine whether such changes in awareness or concern were due to the implementation of the GDPR.

5.2 Rights to access, rectify and restrict the processing of personal information

The GDPR ensures that consumers have the right to view a copy of their personal information that a company has collected and stored. Although very few of our respondents indicated that they had availed themselves of this new option, 60% said that they might do so in the future, and only 23% said that they did not expect to. This suggests that consumers are somewhat concerned about what data are being stored and that they want at least some control over access to their personal data. Among the eight comments we received on this topic, three specifically mentioned Facebook: *'Have done this with Facebook—meaning downloading the data they have about me—or, at least what they want me to think they have'*; *'Scary to read what Facebook knows about me—even stuff I have deleted earlier'*; and *'Have downloaded my data from Facebook for two reasons: backup, and to see what they look like'*. Another participant claimed that several companies did not comply within 30 days. The importance of consumer access is thoroughly addressed in Mason's PAPA framework [2]. Mason describes one case where a bank customer was wrongfully accused of not paying back his house loan. This was in the mid-1980s and the customer had proof of payment in the form of a booklet with a stamp, but the bank refused this evidence and said that it was not registered in the IT system. When the customer finally got enough resources to sue the bank his wife had suffered as stroke due to stress. The family got a settlement in cash, but no excuse. The GDPR now allows consumers in the EU/EAA to see what information of theirs is being recorded and stored and gives these consumers a right to rectify errors; however, none of our participants said that they had made any rectifications.

5.3 Right to erasure ('right to be forgotten')

Under the GDPR, consumers also have the right to have some of their personal data deleted. This applies to information that companies have collected and stored about an individual—although it is also important to note that the GDPR does not include a right to have *all* one's data deleted, only select portions of it. For example, if a customer chooses to pay with a credit card, the record of this transaction and associated data cannot be deleted.

Among our respondents, 68% believed that they might want to ask a company to delete their data and 15% had already done so. This provides further evidence that privacy issues concern many consumers. How organisations will enact such requests in practice remains of interest, as it will require additional work. In many companies, it can require changes in routines, data systems and resource prioritisation. The six comments that we received on this topic mostly expressed some scepticism. Reasons for their scepticism included a lack of information on how to erase their data and statements such as *'I no longer know which companies possess data about me'*. One participant stated that they planned to delete their personal data on Google and Facebook once they figured out how. However, another comment stated that *'I will most likely not pursue this. From the advertisements that Facebook continuously shows me, I draw the conclusion that they do not really know too much about me as a person'*.

Respondents' concerns on this topic are understandable: how can we, as consumers, really know if an organisation has indeed deleted all our personal data? Respondents expressed scepticism regarding both the organisations' *will* to delete information as well as their *capacity* to do so. (However, we must remember that GDPR does not give us the right to have all data deleted. As previously stated: if a customer chooses to pay with credit card this transaction data cannot be deleted). Extant literature has repeatedly highlighted this issue, and some have claimed that it is impossible for companies to fully comply with the GDPR regarding 'the right to be forgotten' [21]. We asked the Norwegian Data Protection Regulation office for advice on how an individual can assure deletion; they responded that a consumer has to trust the organisation, although they can also pay attention to the marketing that they receive from that organisation

afterwards. Also, a consumer can execute their right to data portability to later check if the data in question are in fact deleted, as we discuss in the next section.

5.4 Right to data portability

Data portability is a key part of the GDPR and means that consumers can ask a business to transfer all of their personal data to a competing company, thus giving consumers greater control over their personal information and making it easier for consumers to switch from one company to another. Our survey results indicated that respondents held somewhat mixed views on this topic: 41% stated that they might take advantage of this and 36% stated that they probably would not (12% were uncertain). Only 7% had previously attempted this. We received 13 comments on this question. Notably, 3 specifically stated that they had asked Facebook to send them all their accumulated data, but they did not elaborate further. Facebook has indeed made it possible for consumers to access this right, as illustrated in Figure 1 below. A Facebook user can monitor his or her information in five ways: access the information; download (thus facilitating the rights of data portability); view the activity; managing the information; and deleting their profile. Assessing how well Facebook fulfils these five rights is beyond the scope of this study.

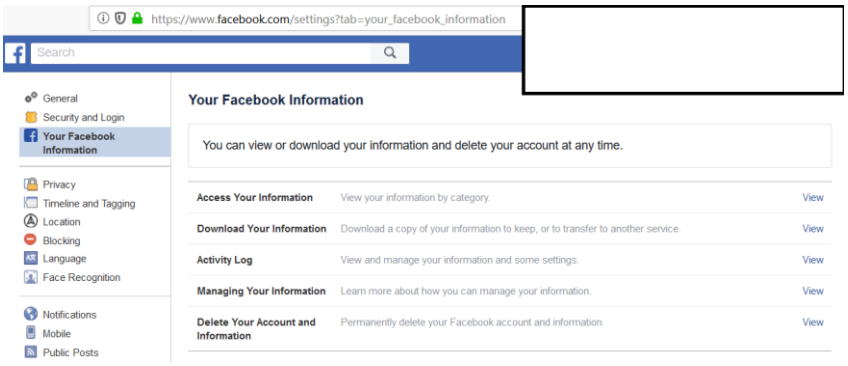

Fig. 1. Screenshot of Facebook's information privacy features for users

On the one hand, we observe that consumers are somewhat carefree when it comes to their personal data [6], but on the other hand, it seems that consumers place a high price on it. For example, David Jacoby, an international security analytic, said that his friends assessed their Facebook-account to be worth approximately 50.000 Euro [25]. However, the price on the dark web is about 1 Euro and this also illustrates the mismatch between the users' perceptive and the hackers in general. It may also illustrate the privacy paradox which we return to in Section 5.7.

Other comments came from respondents who indicated that they might execute this right of data portability in the future: '*This is a good initiative. For example, if I want to change opticians, I can easily ask them to transfer my information to another optician's shop, meaning that I will not have to undergo new visual examinations.'* However, other respondents expressed some concern about how this will be handled by companies.

5.5 Right to object

Although consumers have the right to object to a website or application's 'terms and conditions', our results indicate that consumers were very quick to approve them even though it was quite clear that they were not very familiar with the content; without reading it, they trusted that it was acceptable. Only 1% of our respondents stated that they took the time to read the entire text, while 17% scrolled through quickly and did not read everything. Over 60% clicked on 'accept' without reading the text at all (the remaining 20% reported that their reactions vary). Even though most of our respondents stated that they cared about privacy, the majority were unlikely to spend time reading the terms and conditions of a programme they were downloading. We received nine comments on this topic, most expressing the view that such texts were too long or too difficult to understand.

The GDPR also allows consumers to choose to accept some but not all website cookies when visiting a website. Companies should therefore disclose the purpose of the personal data stored by each cookie. Since the GDPR came into force many companies have implemented this feature and visitors to a website now often encounter pop-up information boxes describing the website's cookie use. Almost half of our respondents felt that companies have become much better at informing website visitors about cookies since the implementation of the GDPR. Just under 30% stated that they felt uncertain about what companies do with cookies, and just over 20% claimed that companies give consumers the opportunity to opt out of some cookies. This topic also seemed to be of interest to our respondents, as 23 chose to leave additional comments. These comments indicated three main areas of concern: (i) the pop-up boxes with cookie information are more irritating and annoying than before GDPR, (ii) it is not possible to choose to accept only some cookies and (iii) the option to deny cookies was irrelevant, since *'you cannot have any websites without cookies anyway'* and *'it is not really the cookies that pose a threat to my information privacy'*.

The GDPR also gives consumers the right to object to direct marketing (such as personalised advertising). We found that attitudes towards this topic were fairly mixed: 32% of our respondents had made use of this ability, while 36% said that they might do so in future and 22% said that they most likely will not. The 24 comments we received on this topic were on the whole more positive than the comments we received about cookies. In general, they expressed happiness about the ability to opt out of receiving newsletters and personalised recommendations. However, some comments pointed to the fact that marketing is necessary. Other comments stated that *'I would rather get personal recommendations than generic commercials*' and *'If my personal data are only used to present me with direct marketing, I see no problem'*.

User consent to terms and conditions, the use of cookies and direct marketing can be a double-edged sword. For example, to a greater extent than before the implementation of GDPR, consumers have now become accustomed to approving the use of website cookies. However, so long as consumers do not bother to read the text, this can function as a trap [26]. In other words, although consumers have now become accustomed to clicking on statements such as 'I understand that this website uses cookies', we suspect that the average consumer does not always understand what cookies really are and their potential consequences, even though very few of our respondents admitted to not knowing what cookies are (3 respondents in the pre-GDPR study and 1 participant in the post-GDPR study). However, it is one thing to know what cookies are and another to fully understand how they can be (mis)used. 27% (87) participants agreed with the statement *'I am unsure what the companies are doing regarding cookies'*. Cookies typically include login information, user preferences and/or online shopping cart information. In addition, third-party cookies communicate collected data to advertisers and flash cookies can continue to collect and track a user's data even after a user has deleted their cookies [27]. Moreover, the new and overwhelming use of pop-up boxes stating that 'this website uses cookies' may lead companies to feel that this justifies their abuses of consumers' personal data.

5.6 Automated, individual decision making

The increasingly widespread usages of algorithms, artificial intelligence and big data (such as high-volume, high-speed and highly heterogeneous data) were drivers for the development of the GDPR [9, 28]. The GDPR does not forbid the use of such technologies, but calls for greater transparency about their use. These technological advances make human participation redundant in a continually increasing percentage of decisions, such as whether an individual qualifies for a mortgage loan, whether an immigrant should be granted citizenship or how long a convict should be sentenced to prison. In schools, multiple-choice exams have long been used to calculate student grades, but it is now also possible to for algorithms to grade unstructured essays without the involvement of a human instructor [6].

A large majority of our respondents were happy to receive personalised suggestions on Netflix or similar services (83%) or for other products that might be of interest to them, for example on Amazon (73%). Half of our respondents also felt that it was acceptable to use artificial intelligence in connection with insurance and student loan decisions. However, less than 30% of respondents were comfortable with the use of artificial intelligence to determine consumer eligibility for mortgage loans, and only about 25% of respondents believed that it should be used to decide whether an individual was entitled to compensation after being robbed. Moreover, only about 15% of respondents agreed that artificial

intelligence should assess exam results. The 21 comments that we received on the topic of automated decision making were largely in agreement with each other and reflected the results noted above. Regarding critical decisions such as mortgage and student loan eligibility, the comments indicated an acceptance of algorithms being used as a component of the decision making process, but felt that a human should be involved in the final decision. They also very clearly indicated a desire for transparency about the use of automated decision making and a belief that consumers should have the right to appeal automated decisions. Consistent with our previous study [6], we found that the use of algorithms and artificial intelligence was more accepted in decisions with fewer consequences, such as movie recommendations. It is nonetheless noteworthy that as many as 15% accepted the use of artificial intelligence in assessing exams, and it will be interesting to follow technological and societal evolutions on this topic [29].

5.7 Territorial scope, trade for benefits

Almost everyone who participated in our survey said they were willing to disclose their first name (90%) on websites and most were also willing to disclose their last name (74%), in order to receive perceived benefits. Most were also willing to leave an e-mail address (80%) and roughly half of respondents were also willing to provide their date of birth and to list the kinds of products they purchased and what kinds of television they watched. However, few people wanted to divulge their iris patterns, fingerprints or bank card numbers; these are highly personal data that consumers wanted to keep private. Interestingly, although we only received five comments on this topic, all of them expressed satisfaction with Facebook, in particular, being affected by the GDPR. One comment stated that *'I have a love/hate relationship with Facebook. I have no doubts that they have sold my personal data'*. We also asked respondents about their willingness to trade their personal data for perceived benefits, such as corporate discounts or improved services. The 12 comments that we received on this topic primarily referred to two issues: the amount of trust a consumer placed in a given company and the fact that people tend to say one thing and yet do another (often referred to as the privacy paradox) [12].

5.8 Final comments

Finally, at the end of the survey we allowed respondents to leave any comments about the survey itself. Of the eight comments we received here, half were positive and called the survey interesting or eye-opening, while three stated that it was cumbersome and that the questions took too long to read. We found the final comment intriguing: *'I am personally against the whole GDPR. "The right to be forgotten" is incompatible with the very existence of the Internet. […] The future is a decentralized internet, with blockchain technology and immutable data. The GDPR is an infringement of the private sphere […] and people should react accordingly.'* We certainly agree that the GDPR is not a silver bullet that will solve all challenges to information privacy, and Section 5.5 points to some evidence of the GDPR working against its intended purpose. However, the GDPR has also initiated a useful discussion on the tangible implications of information privacy, to which we hope our present discussion of selected topics can meaningfully contribute.

Overall, our findings largely confirm prior research, especially regarding the privacy paradox. We found that consumers possess a high degree of knowledge about their rights and the GDPR; however, they typically stated that they *might* execute their rights, and only 5–30% (depending on the specific topic) actually *had* executed their rights. Although consumers are now better informed, few have taken any action to take advantage of their increased rights.

5.9 Limitations and suggestions for future research

This study was mainly descriptive and offered insights from a consumer perspective. The GDPR is a new regulation that affects any organisation dealing with personal data and consumers in the EU and EEA. Currently, our knowledge is still limited regarding how it will influence various stakeholders. The aim of this study was therefore to establish a foundation one year after its implementation. We hope that future research will build on our findings, and we suggest in-depth qualitative interviews with consumers and case studies about how companies can meet the new consumer data requirements. Although our findings indicate that consumers are only somewhat likely to execute their new rights to

information privacy, this may change over time as dynamics evolve between technologies, policies, processes, society and the economy [13, 28]. This topic remains of interest to the field of information systems and project management.

6. Conclusion

Our research responds to prior calls for more insights regarding what consumers actually think and how they act. Based on two surveys conducted prior to (n = 216) and following (n = 327) the implementation of the GDPR, we offer three main insights. (1) Within a year, consumers gained increased knowledge about their information privacy; however, they remained fairly unconcerned about executing their enhanced rights. (2) Beliefs about personal control of one's own data were highly mixed: about 50% of respondents felt that they had control of their personal data, while almost 40% stated that they had no control over their personal data. (3) A recurring issue was consumers' trust in companies' management of their personal data. The present research can contribute to the field's understanding of consumer views of information privacy and the GDPR. While the GDPR is not likely to solve all problems pertaining to information privacy, it remains an interesting and relevant subject for future research.

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Appendix: Questionnaire

- Gender
- Age
- Main occupation
- Level of privacy concern in general

You have the right to object to companies sending you direct marketing (in the form of personal customised advertising).
[I have executed this right - I might execute this right - I will most likely not execute this right - I do not care - I do not know]

To what extent do you find that your personal information exists in places that you do not have control over? (E.g., information stored in databases of different businesses)
[I have control over everything - I have a lot of control - I have partial control - I have no control at all - I do not care about it]

On July 20, 2018, the GDPR (General Data Protection Regulation) was introduced in Norway. Have you heard about it? (before you started answering this survey)
[Yes, and I know what that means - Yes, I know a little, but not enough about what it means - Yes, but I didn't know what that meant - I had never heard of that]

The GDPR means that individuals have gained new rights regarding the collection and storage of personal data. What do you think about that?
[I think my rights have improved - I don't think my rights have improved - I don't care at all - Do not know]

Data portability is a key part of the GDPR. This means that you can transfer all your data that one business has saved. You can require existing business to send your data to, for example, a competitor business. What do you think about this?
[I have executed this right - I might execute this right - I will most likely not execute this right - I do not care - I do not know]

The GDPR has given you a greater right to demand that some personal information (that companies have collected) about you will be deleted. What do you think about this?
[I have executed this right - I might execute this right - I will most likely not execute this right - I do not care - I do not know]

The GDPR gives you the right to receive a reply within 30 days when you approach businesses with questions related to your data. The overview should be sent in a readable format and you can correct any errors. What do you think about this?
[I have executed this right - I might execute this right - I will most likely not execute this right - I do not care - I do not know]

The GDPR says that you can choose to accept some cookies, but not all, when you visit a website. In addition, the purpose of the data stored about you should be more disclosed. What do you think about this? (Check all appropriate options.)
[Companies have become much better at informing website visitors about cookies - Companies allow me to opt out of some cookies - I am unsure what companies actually do when it comes to cookies - I do not care - Do not know what cookies are]

Artificial intelligence makes it increasingly possible for companies to make automated decisions without the involvement of a human. I think it's okay that a machine algorithm performs and calculates the following: (check all appropriate options).
[Whether or not I get a mortgage - The price of my insurance - How much I will receive in student loans - My examination assessments and determinations of my grades at school - What movies I should watch on Netflix (or similar services) - What products have been purchased by others who also bought an item I bought on Amazon (or similar online store) - Whether I am entitled to compensation if I am stripped of an asset]

When you download an app on your cell phone or install a programme on your laptop, you must approve the terms and condition. What is your typical reaction?
[I read the whole text, even though it takes a long time - I quickly scroll through the entire text, but do not read everything - I click on "I agree/accept" without looking at the text at all - It depends from time to time (depending on the app/programme in question)]

The GDPR also affects citizens of countries outside the EU/EEA. What do you think about Facebook being affected in the ways mentioned in the other questions (for example, the right to access, rectification and deletion of data)?
[I think it is great that Facebook is affected by the GDPR - I find it unfortunate that Facebook is affected by the GDPR - I do not care at all - I do not know]

Which data are you willing to give up in exchange for better services or discounts?
E.g. [First name - family name - e-mail address - IP-address - fingerprint]

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A comparison of project control standards based on network analysis

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Abstract:
Project control is a crucial function in project management. Over the years, several best practice standards have been developed to assist project managers in improving project control. The objective of this paper is to compare three prominent best practice models of PMBOK, PRINCE2, and the AACE framework with respect to the core processes of project control. Network analysis is used to achieve this objective. The results show that influential and linkage processes, such as Control quality, Review the stage status, Forecasting, and Change management have the most significant impacts on the complexity of the project control function. This work has the potential to help rethink the project control function by creating a more global view of the most central and critical processes for project control, from which enhancement in the ability to control the project can be drawn.

Keywords:
project management; project control; PMBOK; PRINCE2; AACE; network analysis.

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1. Introduction

The role of monitoring and control in project management is to detect potential problems during project execution and to take necessary corrective actions to achieve project performance objectives. Some such objectives are ensuring the schedule and budget are adhered to. Recent studies have, moreover, shown that project control is an essential function towards project success ([1]-[3]). Projects are completed to quality, cost, schedule, and health and safety regulations when monitoring and control is implemented effectively.

Given the essential function of project control in project management, different methodologies, such as PMBOK (Project Management Body of Knowledge) and PRINCE2 (PRojects IN Controlled Environments), and their underlying tools, techniques, and processes have been increasingly adopted by project managers to plan, execute, monitor, and control activities in order to ensure project delivery [4]. Although these project management methodologies share overlapping content, each of the standards offers different advantages. Over the years, several researchers tried to unify the tools, techniques, and practices of various project management standards by integrating and harmonizing different standards so as to implement project management processes more effectively and efficiently ([5]-[9]).

In this paper, network analysis is used to analyze the three standards of PMBOK, PRINCE2, and AACE (Association for the Advancement of Cost Engineering) for the control of projects. Network analysis is an analytical technique evolving from graph theory used in multiple fields including social sciences, natural sciences, construction management, and safety [10]. In construction management, researchers use network analysis in various ways ranging from organizational analysis to team interactions in a construction project [11]. For example, the use of network analysis is gaining popularity in organizational governance and project management and has the potential to map temporal construction project-based organizations as networks to examine the interactions between stakeholders within the network boundary [12]. Network analysis is also used to investigate the structure of a network where nodes represent parties or team members and links represent the relationships between them [11].

In a previous paper [13], we used network analysis to characterize the most central processes of the two standards of PMBOK and PRINCE2 for the control of projects. In this paper, we propose to extend the analysis by examining and comparing PMBOK, PRINCE2, and AACE control processes in order to identify their most central and critical processes. The characterization of central features of project control within each standard will be achieved using network analysis.

The reminder of this paper is organized as follows. Section 2 provides an overview of recent work in the fields of project control and network analysis. Section 3 presents the three project control standards – PMBOK, PRINCE2, and AACE – the methodology for constructing the associated network models, and the statistical measures to analyze them. In Section 4, the three network models are analyzed and the key processes of project control are categorized. Conclusions are finally drawn in Section 5.

2. Literature background

2.1 *Project control and project management standards*

Project control is a critical function in project management. Project control evaluates actual performance and resolving any deviations from planned performance during project execution. This is a significant phase towards project success. To facilitate project control, quantifiable performance metrics are typically defined before a project starts. These metrics reflect the critical success factors as well as project objectives, such as cost, time, quality, safety, productivity, and scope of work.

Recently, Al-Tmeemy and Al Bassam [1] showed that cost of control activities significantly enhance project management success in terms of adherence to budget, schedule, and quality target. Demachkieh and Abdul-Malak [2] confirmed the relevance for enhancing the efforts, systems, or mechanisms required for implementing effective monitoring and control for the success of projects in all industries. The benefits of project monitoring and evaluation

has also been demonstrated by Callistus and Clinton [3] who emphasized the critical role of monitoring and control in the management of construction projects throughout the entire life cycle of project delivery. For a more thorough review of project control, the interested reader is referred to the recent work of Pellerin and Perrier [14].

To ensure the delivery of a project, project managers need to utilize proper project management methodologies. Nowadays, many standard methodologies on project management are available [15]. Standards worth mentioning include PMBOK, PRINCE2, ISO, BS 7000-2:2008, APMBOK, and ICB. Recently, some of these standards, e.g., PMBOK and PRINCE2, have been demonstrated to be useful to either effectively evaluate an organization's current project management maturity level (e.g., [16],[17]) or to apply project-based processes for the implementation of change management initiatives [18]. Others, like the AACE (Total Cost Management) framework for project control plan implementation, have been used to classify the current literature in the context of organizations involved in the social economy and solidarity economy [19]. These project management methodologies have also been continuously refined to reflect advances in project management knowledge database [16] and to facilitate the communication, the understanding, and the application of these standards [4].

Given that each standard methodology has its own strengths and limitations, several authors recommended using different standards as complementary to each other. Also, researchers tried over the years to create a unified methodology proposal that integrates the strengths of two or more best practices. For example, von Wangenheim et al. [5] proposed a unified set of best practices for project management by integrating PMBOK and CMMI (Capability Maturity Model Integration) models. Madani [6] designed a framework to integrate knowledge management and PMBOK processes. Mesquida et al. [7] used the PMBOK guide to complement the ISO/IEC 29110-5-1-2 standard. Brioso [8] suggested that the management standards used in construction, such as the PMBOK and PRINCE2, among others, may be made compatible through the ISO 21500 standard to allow sequences and the adaptation of processes to be carried out in a flexible way. More recently, Isacas-Ojeda et al. [9] presented an integrated model for managing civil construction projects based on the best practices of the PMBOK and international standards governed by ISO 21500 in project management.

2.2 *Network analysis*

Based on sociometrics and graph theory, network analysis uses statistical tools to analyze the impacts of nodes (e.g., actors or parties) and links (e.g., interactions between different nodes) in a particular network and to help understand the network relationship through describing, visualizing, and statistical modeling ([11],[20],[21]).

Along with its dominant use in sociology and organizational research, network analysis has been used in a variety of disciplines including electrical power grids, wastewater, transportation, communication, biology and medical, and ecological [11]. Network analysis has also become increasingly popular in different areas of construction management research over the last two decades, including the areas of supply chain management, on-site operational management, and health and safety issues [11],[12]. One theoretical bridge to using network analysis in construction is to view construction project-based organizations as a set of networks. Network analysis provides a way to represent and understand project-based organizations by translating them into networks thus allowing innovative studies of organizational relationships [12]. In recent years, the use of network analysis to study project-based organizations in the construction sector has increased [22].

Specifically, network analysis has been applied to project management for the purposes of analyzing interdependencies within a project portfolio [23], examining the relationship between project performance and organizational characteristics in construction companies [22], as well as identifying the major risks embedded either across the supply chains of prefabricated building projects [24] or in international construction projects [25]. Network analysis has additionally been applied in construction projects to identify and model actual social structures, project team interactions, and collaborative project management ([11],[12],[20],[21],[26]) and also to enable the detection of relationships between causes of fatal accidents [10].

3. Project control standards and network centrality measures

In this section, we briefly review the main project control concepts introduced by three widely used standard and structured project management methodologies: PMBOK, PRINCE2, and the AACE framework. We then present the type of network representation that can be used to model these three standards and introduce the statistical measures to analyze them.

3.1 Project control standards

Several best practice models related to project management provide specific guidelines for controlling projects and describe the related processes. In this respect, PMBOK, PRINCE2, and the AACE framework represent three collections of best practices that have a project control focus. First, PMBOK (Project Management Body of Knowledge) is a classic project management methodology developed by the Project Management Institute [27]. In PMBOK, project management is accomplished through the application and integration of 47 project management processes that cover the entire project life cycle, from proposal to delivery, final acceptance, and closing. Among these, eleven monitoring and controlling processes are required to track, review, and regulate the progress and performance of the project, identify any areas in which changes to the plan are required, and initiate the corresponding changes (Table 1). Each control process in PMBOK is characterized by its inputs and the resulting outputs to meet the objective of the process (for the detailed inputs and outputs, please refer to Table 4 in Appendix A).

Table 1. PMBOK project monitoring and controlling processes

Process	Description
Monitor and control project work	Tracks, reviews, and reports the progress to meet the performance objectives defined in the project management plan
Perform integrated change control	Reviews all requests for changes or modifications to project documents, deliverables, baselines, or the project management plan, and approves or rejects the changes
Validate scope	Formalizes acceptance of the completed project deliverables
Control scope	Monitors the status of the project and product scope and manages changes to the scope baseline
Control schedule	Monitors the status of project activities to update project progress and manage changes to the schedule baseline to achieve the plan
Control costs	Monitors the status of the project to update the project costs and manages changes to the cost baseline
Control quality	Monitors and records results of executing the quality activities to assess performance and recommend necessary changes
Control communications	Monitors and controls communications throughout the entire project life cycle to ensure the information needs of the project stakeholders are met
Control risks	Implements risk response plans, tracks identified risks, monitors residual risks, identifies new risks, and evaluates risk process effectiveness throughout the project
Control procurement	Manages procurement relationships, monitors contract performance, and makes changes and corrections to contracts as appropriate
Control stakeholder engagement	Monitors overall project stakeholder relationships and adjusts strategies and plans for engaging stakeholders

Similarly, PRINCE2 is a process-based methodology for the definition, execution, and monitoring of projects that has been introduced by the UK's Office of Government Commerce. PRINCE2 contains seven inter-linked major processes, including one project control process that is a set of eight activities to be undertaken during the project life cycle. The project control process in PRINCE2 ensures that project objectives are met by measuring progress and taking corrective actions when necessary. This process includes collecting project progress status, analyzing variances, and communicating project status. Table 2 shows the eight project control activities in PRINCE2 [28]. Each control activity has its corresponding inputs and outputs, 41 in all (see Table 5 in Appendix A).

Table 2. PRINCE2 project control activities: inputs (I) and outputs (O)

Activity	Description
Authorize a work package	Assigns and agrees a work package with the team manager
Review work packages status	Checks on work package progress
Receive completed work package	Checks quality and configuration management
Review the stage status	Continually compares status to stage plan
Report highlights	Regular reports to the project board
Capture and examine issues and risks	Categorizes and assesses impact
Escalate issues and risks	Creates exception report and sends to the project board
Take corrective action	Solves issue or risk while keeping stage within tolerance

With a great focus on project control, the AACE framework is an integrated approach to portfolio program and project management introduced by the Association for the Advancement of Cost Engineering International. The distinguishing feature of the AACE model is that it offers a systematic approach to managing cost throughout the life cycle of a project while using Deming's wheel of quality (Plan-Do-Check-Act) to pinpoint and categorize activities. The AACE standard defines four project control processes divided into thirteen sub-processes. Table 3 presents the AACE model's project control processes and sub-processes [29]. All processes and sub-processes interact with one another through inputs and outputs (see Table 6 in Appendix A).

Table 3. AACE project control processes and sub-processes

Processes	Sub-processes	Description
Project control planning	Project scope and execution strategy development	Translates the project implementation basis (i.e., asset scope, objectives, constraints, and assumptions) into controllable project scope definition and an execution strategy that establishes criteria for how the work will be implemented.
	Schedule planning and development	How plans develop over time in consideration of the costs and resources for that work.
	Cost estimating and budgeting	Quantifies, costs, and prices the resources required by the scope of an investment option, activity, or project, and allocates the estimated cost of resources into cost accounts (i.e., the budget) against which cost performance will be measured and assessed.
	Resource planning	Ensures that labor, materials, tools, and consumables, which are often limited in availability or limited by density, are invested in a project over time in a way that successfully, if not optimally, achieves project objectives and requirements.
	Value analysis and engineering	Improves the value for the intended asset or project objectives as defined by the respective strategic asset requirements or project implementation basis inputs.
	Risk management	Establishes objectives, identifies risk drivers occurring throughout the project or asset lifecycle, and essentially manages that risk by continually seeking to assess, treat and control their impacts.
	Procurement planning	Ensures that information about resources (e.g., labor, material, etc.) as required for project control is identified for, incorporated in, and obtained through the procurement process.

Processes	Sub-processes	Description
Project control plan implementation	–	Integrates all aspects of the project control plan; validates that the plans are comprehensive and consistent with requirements and ready for control; initiates mechanisms or systems for project control; and communicates the integrated project control plan to those responsible for the project's work packages.
Project control measurement	Project cost accounting	Measures and reports the commitment and expenditure of money on a project.
	Progress and performance measurement	Measures the expenditure or status of non-monetary resources on a project (e.g., tracking the receipt of materials or consumption of labor hours) and the degree of completion or status of project work packages or deliverables (e.g., the extent that materials have been installed, deliverables completed, or milestones achieved), as well as observations of how work is being performed (e.g., work sampling).
Project control performance assessment	Project performance assessment	Compares actual project performance against planned performance and identifying variances from planned performance.
	Forecasting	Evaluates project control plans and control baselines in consideration of assessments of ongoing project performance.
	Change management	Manages any change to the scope of work and/or any deviation, performance trend, or change to an approved or baseline project control plan.
	Project historical database management	Collects, maintains, and analyzes project historical information so that it is ready for use by the other project control processes and for strategic asset management.

3.2 Network representation and centrality measures

Network analysis is used in this paper to identify the central processes of three project control standards: PMBOK, PRINCE2, and the AACE framework. The actual structure of each project control standard can be modeled by a directed graph $G = (V, A)$ where $V = \{v_1, v_2,..., v_n\}$ is the vertex set and $A = \{(v_i, v_j) : v_i, v_j \in V \text{ and } i \neq j\}$ is the arc set. Vertices $v_1, v_2,..., v_n$ correspond to processes, sub-processes, inputs or outputs. Arcs are used to represent relationships between vertices, namely the inputs and outputs of each process or sub-process. Specifically, if v_j is a process and (v_i, v_j) and (v_j, v_k) are two arcs connecting pairs of vertices, then the vertices v_i and v_k are called the input and output of the process v_j, respectively.

In network analysis, measures of centrality are key statistical indices to identify the most important vertices in a network ([10],[20]). Three centrality metrics were used in this research: degree centrality, betweenness centrality, and closeness centrality. The higher the centrality value represents a more core position of a vertex in a network and reveals the greater extent to a vertex affects others [21]. Degree centrality is an indicator of the extent to which a vertex depends on others, or to which other vertices are dependent upon it [23]. A vertex with a large number of incoming arcs transmitted to it is highly dependent on other vertices and is said to have high *indegree* centrality. Similarly, a vertex with high *outdegree* centrality emits a large number of outgoing arcs and has many vertices dependent on it. Therefore, the indegree centrality can be seen as a measure of dependence or support, while the outdegree centrality can be considered as a measure of independence or influence [30].

Another way to measure the importance of a vertex is to examine the extent to which a vertex is located upon the geodesic distance or shortest path between every pair of the remaining vertices [23].(The shortest path from one vertex to another is the sequence of arcs connecting between these two vertices and consisting of the least number of arcs). This measure, called *betweenness* centrality, has been linked for example to the potential control and impact that a vertex can exercise in the network [20], the intermediary, channelling and mediating functions in controlling and transferring information flows within the network ([12],[23],[31]), as well as how influential a particular vertex is within the network [10]. A high betweenness centrality vertex has more control within the network, assuming more information is flowing through that vertex, and greater capacity to influence the other vertices [20]. Vertices with high betweenness centrality are the hubs in the network to connect many pairs of vertices and consequently lead to impact propagation and complex vertex interactions across the network [24]. Therefore, these vertices should be monitored to reduce the complexity of the network.

Finally, the *closeness* centrality measure describes the ability to reach a vertex in a network. Formally, this measure can be defined as the inverse of the average length of the shortest paths from all vertices to a given vertex in the network. A higher closeness centrality vertex has thus the ability to quickly acquire information through the other vertices [32]. In some way, the closeness centrality measure denotes the degree of autonomy or independence of a vertex ([20],[21]).

4. Results

This section examines the three networks of PMBOK, PRINCE2, and AACE for project control. For each of the three project control standards, a network model is first developed to pinpoint the core processes of the network. The results of the three models are then interpreted and validated through network centrality measures to identify the key processes of project control and the interrelationships among them. The three network models were constructed and analyzed in *R* (version 3.2.4) using the networkD3 package. The Fruchterman-Reingold force-directed layout algorithm was used for visualizing the networks [33]. In this algorithm, vertex layout is determined by simulating the whole graph as a physical system. Arcs in the graph are seen as springs binding vertices. Vertices are pulled closer together or pushed further apart according to attractive and repulsive forces, respectively. The objective of the algorithm is to minimize the overall energy of the whole system by adjusting the positions of the vertices and changing the physical forces between them to achieve an aesthetically pleasing graph layout.

4.1 Network models

Figures 1, 2, and 3 graphically display the PMBOK, the PRINCE2, and the AACE networks, respectively. The vertex numbers follow the numbering of the information presented in Appendix A in Tables 4, 5, and 6, respectively. Vertex size reflects the number of arcs incident to a vertex (degree centrality value). Thus, a large-size vertex represents the prominence of the vertex. Also, processes in the center of a network represent core items to the project control network. Core items should be controlled first, while the other peripheral items can be discarded or controlled at a later stage.

As shown in Figure 1, *Project management plan* (1), *Work performance information* (5), *Organizational process assets* (7), *Change requests* (10), *Work performance data* (15), *Project management plan updates* (39), *Project document updates* (40), and *Organizational process asset updates* (43) fell at the center of the PMBOK network, suggesting that these eight inputs and outputs may be core to project control. In fact, all the processes of the PMBOK network (8, 11, 16, 17, 21, 23, 29, 32, 34, 37, and 38) gravitate around these core inputs and outputs. Similarly, as shown in Figure 2, the process *Take corrective action* (31) and the inputs *Stage plan* (1) and *Risk register* (12) are at the center of the PRINCE2 network and can thus be considered as core elements to project control. The other seven project control processes (8, 13, 16, 20, 24, 27, and 30) are positioned not so far from the center of the PRINCE2 network.

Figure 3 shows that the AACE network can be divided into several groups: a singleton consisting of the *Project control plan implementation* (8) process falling at the center of the AACE model and considered as a core process to project control; closest to the singleton, a group of three core sub-processes, namely *Project performance assessment* (11), *Forecasting* (12), and *Change management* (13), which are part of the *Project control performance assessment* process; a group of five inputs and outputs (15, 19, 47, 59, and 88) that gravitate around the core sub-processes listed above; a group of six sub-processes located not so far from the center and composed of the following sub-processes: *Project scope and execution strategy development* (1), *Resource planning* (4), *Procurement planning* (7), *Project cost accounting* (9), *Progress and performance measurement* (10), and *Project historical database management* (14); and at the periphery of the network, two distinct groups, each composed of two sub-processes belonging to the *Project planning and control* process: a group made up of the *Schedule planning and development* (2) and the *Cost estimating and budgeting* (3) sub-processes, and another group that includes the *Value analysis and engineering* (5) and the *Risk management* (6) sub-processes.

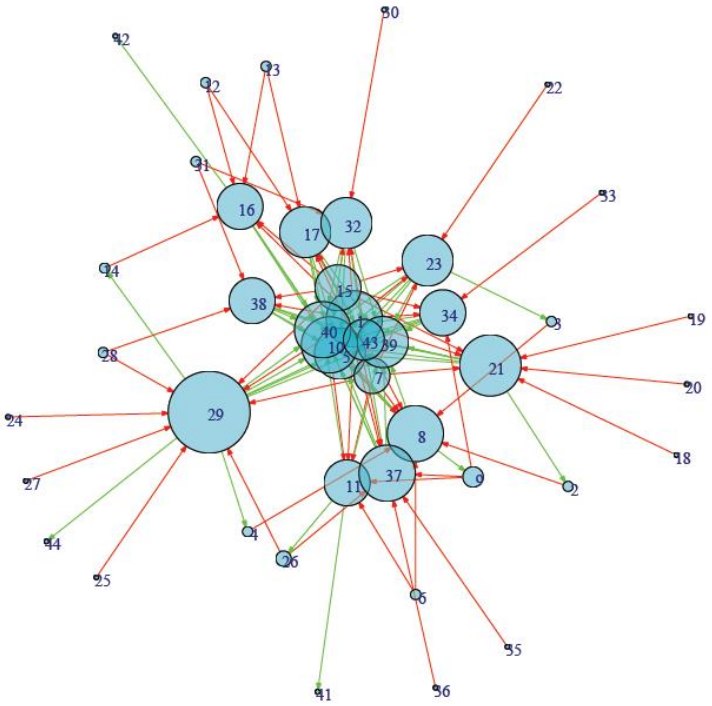

Fig. 1. PMBOK network

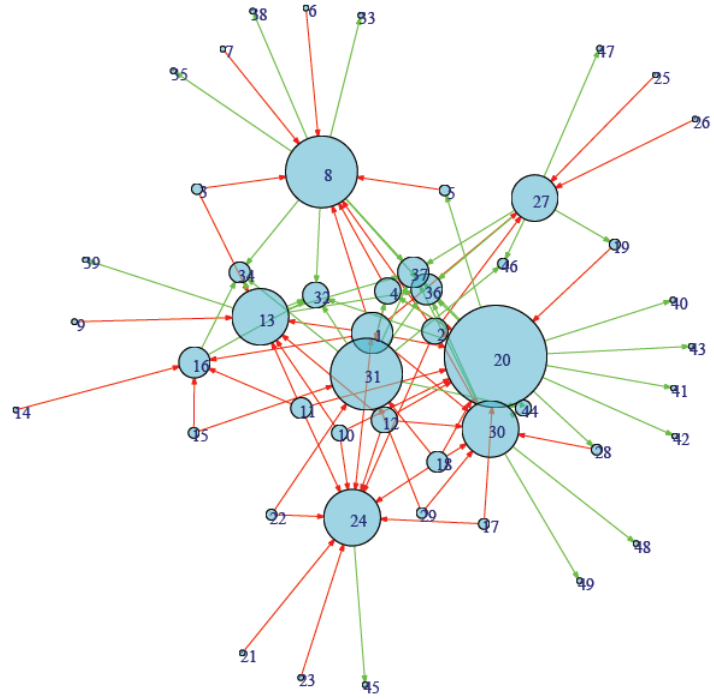

Fig. 2. PRINCE2 network

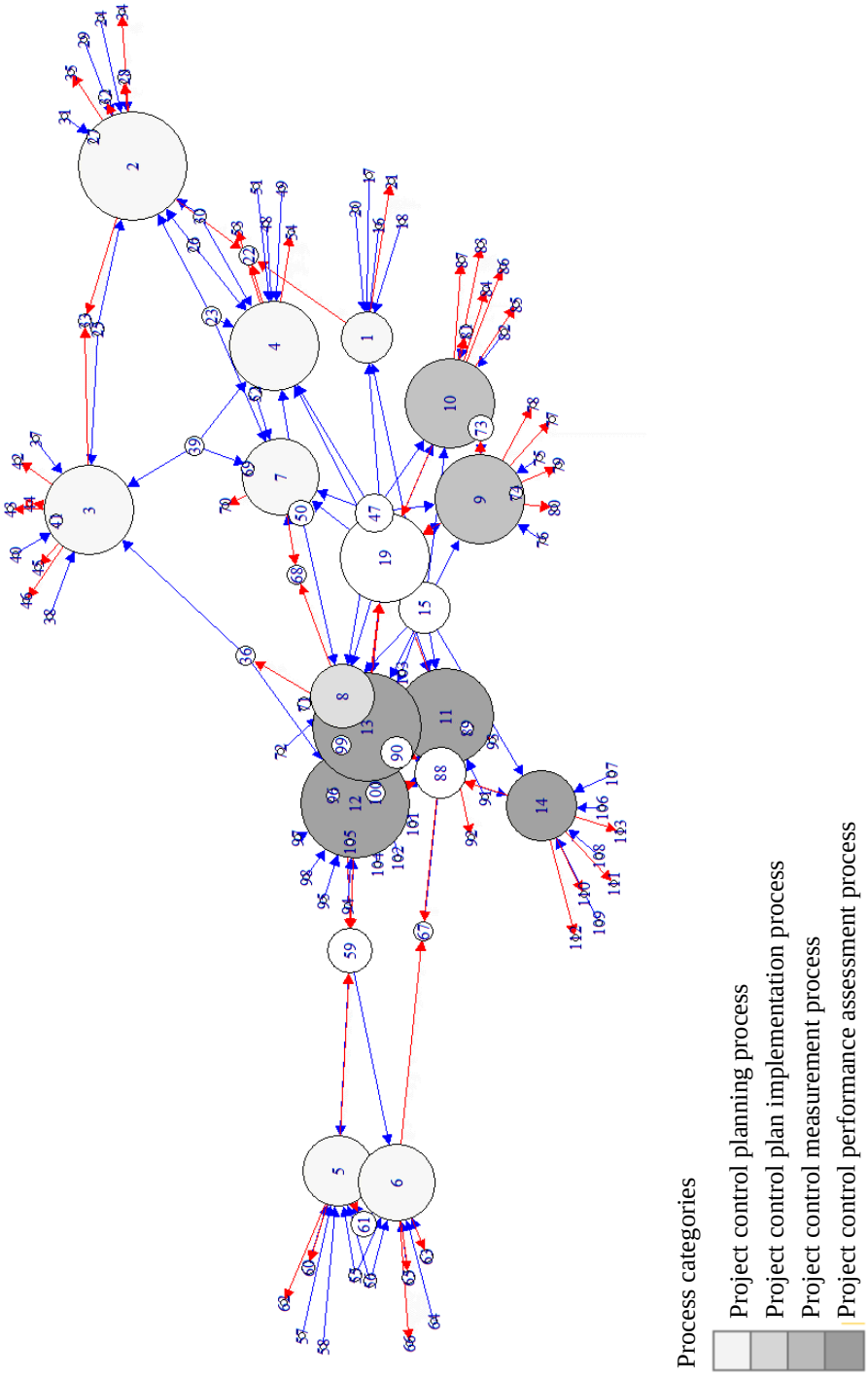

Fig. 3. AACE network

4.2 Centrality indices

Tables 7, 8, and 9 in Appendix B show the centrality metrics for the PMBOK, the PRINCE2, and the AACE networks, respectively. Higher numbers indicate that an item is more central to the network. Highest values within each centrality index are indicated in bold type. Values shown in the three tables in Appendix B are normalized values.

The indices of in-degree centrality and out-degree centrality for the PMBOK network support the finding that *Project management plan* (1), *Work performance information* (5), *Organizational process assets* (7), *Change requests* (10), *Work performance data* (15), *Project management plan updates* (39), *Project document updates* (40), and *Organizational process assets updates* (43) are central inputs and outputs to this network. Other PMBOK items with high in-degree and/or out-degree were the *Monitor and control project work* (8) and the *Control quality* (29) processes. Similarly, for the PRINCE2 network, the indices of in-degree and out-degree centrality also support the results of Section 4.1. The *Stage plan* (1) input as well as the *Review the stage status* (20) and the *Report highlights* (24) processes were the items with the highest in-degree and/or out-degree centrality. On the other hand, as shown in Table 9 in Appendix B, none of the AACE network vertices has a high in-degree or a high out-degree centrality value. All the processes, sub-processes, inputs, and outputs of the AACE framework can thus be considered as self-reliant entities, reducing the complexity of the overall AACE network in terms of network interactions.

To achieve further understanding of the positions of individual vertex and determine the key processes, the betweenness values are analyzed. The results show that *Monitor and control project work* (8), *Change requests* (10), *Perform integrated change control* (11), *Approved change requests* (26), and *Control quality* (29) all have higher betweenness in the PMBOK network model, illustrating that these processes, inputs, and outputs can exert substantial stress on information flow. As highlighted by Xue et al. [20], through the information flow, the items with higher betweenness possess considerable power in the network, because of their extensive potential to control the information flow. These items thus play key roles in the network. Similarly, we found that *Review the stage status* (20) is an important process that builds connections between processes, inputs, and outputs in the PRINCE2 network. Also, although they do not have strong immediate impacts on the others (low out-degree), *Forecasting* (12), *Change management* (13), *Historical Project Information* (19), and *Planning Information* (59) play the important role of hubs in connecting the processes, inputs, and outputs across the AACE network.

Finally, none of the vertices has a high closeness value in the three networks.

In order to classify project control processes within each standard, a scatter graph can be constructed to represent the values of out-degree versus in-degree centrality, from which the vertex types can be allocated to four categories ([23],[24]):

1) vertices with relatively low out-degree centrality and relatively low in-degree centrality, classified as autonomous;
2) vertices with relatively low out-degree centrality but relatively high in-degree centrality, classified as dependent;
3) influential vertices that have relatively high out-degree centrality but low in-degree centrality, indicating their crucial roles in influencing the network; and
4) linkage vertices, which have relatively high out-degree and in-degree centrality.

Influential and linkage vertices are significant vertices given their multiple roles in influencing network interactions [24]. Cancelling, delaying, or significantly altering any one of the linkage or influential processes can have a significant impact on many other processes in the network [23]. The out-degree versus in-degree centralities of each process, input, and output of the PBBOK network are plotted in Figure 4. Most of the PMBOK processes, inputs, and outputs can be classified as autonomous, since they have relatively low in-degree and out-degree centrality values. However, *Work performance information* (5), *Monitor and control project work* (8), *Change requests* (10), *Project management plan updates* (39), *Project documents updates* (40), and *Organizational process assets updates* (43) can be classified as dependent, since they have relatively low out-degree centrality but relatively high in-degree centrality. These items, which are predominantly outputs, can be thus greatly affected by other vertices in a direct way with their high in-degree values. Also, *Project management plan* (1), *Organizational process assets* (7), and *Work performance data* (15) can be classified as independent or influential, since they have relatively high out-degree centrality but relatively low in-degree

centrality. These project control inputs exert strong direct influences on other vertices but receive no impact from the others. Finally, the process of *Control quality* (29) can be classified as a linkage or transmitter project control vertex, since it has relatively high out-degree and in-degree centralities. Given their key function in influencing network interactions, influential and linkage vertices play a primary role in the project control network. The complexity of the entire network after removing these key vertices can be greatly increased. Decision makers should thus in particular focus attention on these processes.

Similarly, for the PRINCE2 network, the out-degree versus in-degree centralities of each process, input and output are plotted in Figure 5. In terms of the vertex type, most of the vertices in the PRINCE2 network are ordinary or autonomous vertices, whereas three of them (24, 1, and 20) increase the complexity of the network. With its high in-degree value, the *Report highlights* (24) process can be classified as a dependent process, meaning that this process is directly affected by other processes, inputs or outputs. Also, the *Stage plan* (1) input is the vertex with the highest out-degree value, so this independent or influential input has the strongest direct impact on the other vertices in the PRINCE2 network. Another important vertex that has great potential to generate more impact is the *Review the stage status* (20) process because it has relatively high out-degree and in-degree centralities. This linkage process leads to the complexity of the entire PRINCE2 network as well. For the AACE network, recall that all the project control processes, sub-processes, inputs, and outputs are autonomous, since none of the vertices has high in-degree or out-degree centrality values (see Table 9 in Appendix B). The AACE project control network can thus be seen as a relatively less complex network in terms of process interactions, while the presence of influential and linkage vertices in both the PMBOK and PRINCE2 networks significantly leads to the overall complexity of these two networks.

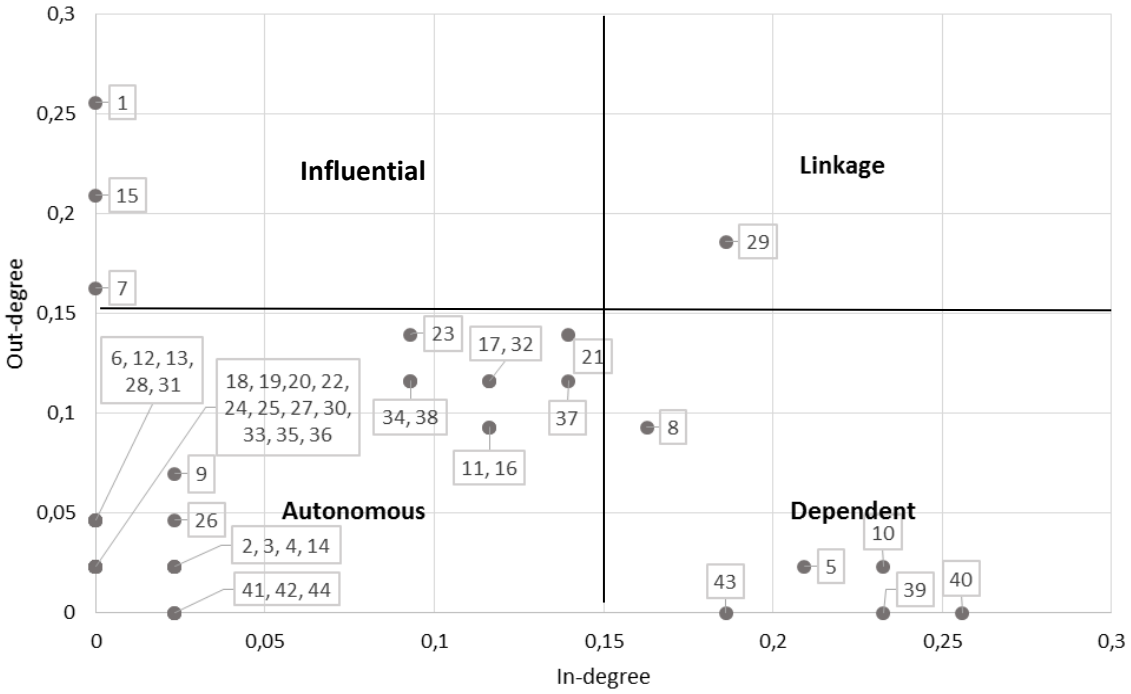

Fig. 4. PMBOK: out-degree versus in-degree centrality diagram

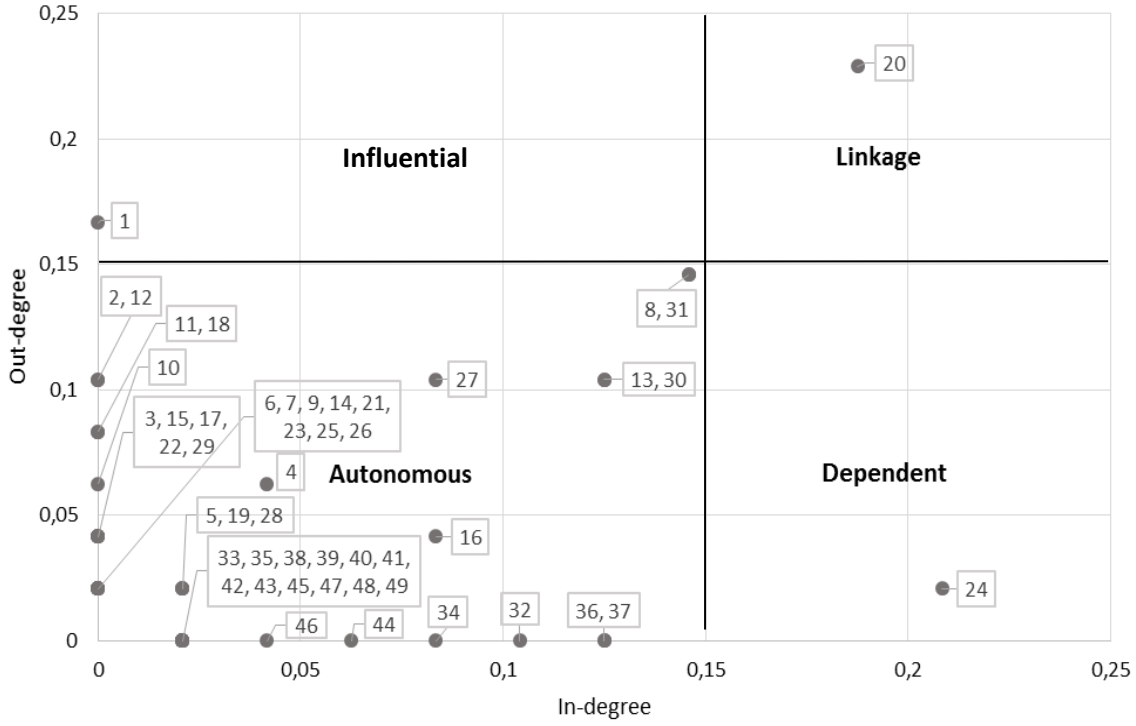

Fig. 5. PRINCE2: out-degree versus in-degree centrality diagram

5. Conclusion

Through network analysis, this paper examined the three standards of PMBOK, PRINCE2, and AACE for the control of projects. The findings showed that several processes, inputs, and outputs are central to project control. In particular, in both the PMBOK network and the PRINCE2 network, key vertices play different roles, such as linking and influential roles, and should be prioritized.

Linkage vertices are special vertices that have high out-degree values. Meanwhile, they are greatly affected by other vertices in a direct way with high in-degree values, indicating that these vertices are in the sensitive locations of the network and significantly lead to the overall network complexity [24]. For example, the *Control quality* (29) process was identified as a linkage process that leads the project control function in the PMBOK network. This finding supports research suggesting that quality is central to project control ([34],[35]). Similarly, the *Review the stage status* (20) process was identified as a linkage vertex in the PRINCE2 network. In addition, these two linkage processes have a high betweenness centrality, meaning that these processes should be regarded as significant channels in the network to gain access to information. Linkage processes are the most difficult processes to manage, since they depend on many other processes, while at the same time many other processes depend on them. Decision makers should thus pay particular attention to these processes.

The study also identified several influential vertices of project control. Influential or independent vertices have higher impacts on other vertices (high out-degree) compared with the impacts they receive (low in-degree). Interestingly, these vertices relate primarily to inputs throughout each network. In the PMBOK network, three influential inputs of project control were identified: *Project management plan* (1), *Organizational process assets* (7), and *Work performance data* (15). Similarly, the *Stage plan* (1) input was identified as highly central to project control and highly influential in the

PRINCE2 network. These inputs have direct impacts on a large number of vertices, leading to the complexity of the entire network, and should thus be given particular attention by project managers.

In contrast with both the PMBOK and PRINCE2 networks, it is worth noting that all the vertices in the AACE network were identified as autonomous with relatively low out-degree centrality and relatively low in-degree centrality, suggesting that none of the AACE vertices need specific attention. However, when analysing vertices with high betweenness centrality, we found that *Forecasting* (12), *Change management* (13), *Historical Project Information* (19), and *Planning Information* (59) are important hubs in the AACE network that build connections between vertices and consequently lead to impact propagation. These processes, inputs, and outputs must therefore be properly tracked to reduce the complexity of the network.

This study was limited to the analysis of the PMBOK, the PRINCE2, and the AACE framework project control processes. The use of network analysis in analysing other standards, such as PMI Foundational Standards, PMI Practice Standards and Frameworks, PMI Standards Extensions, ISO 1006, P3M3, Australian Institute of Project Management, HERMES, and Information Technology Infrastructure Library, and at additional phases of a project's life cycle (e.g., initiation, planning, execution, and closure) will enable a broad comparison between different standards at different phases.

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Appendix A. Inputs and outputs of project control processes

A.1. Detailed inputs and outputs of the PMBOK project control processes

Table 4. PMBOK project control processes: inputs (I) and outputs (O)

Processes	(1) Project management plan	(2) Schedule forecasts	(3) Cost forecasts	(4) Validated changes	(5) Work performance information	(6) Enterprise environmental factors	(7) Organizational process assets	(9) Work performance reports	(10) Change requests	(12) Requirements documentation	(13) Requirements traceability matrix	(14) Verified deliverables	(15) Work performance data	(18) Project schedule	(19) Project calendars	(20) Schedule data	(22) Project funding requirements	(24) Quality metrics	(25) Quality checklists	(26) Approved change requests	(27) Deliverables	(28) Project documents	(30) Project communications	(31) Issue log	(33) Risk register	(35) Procurement documents	(36) Agreements	(39) Project management plan updates	(40) Project documents updates	(41) Change log	(42) Accepted deliverables	(43) Organizational process assets updates	(44) Quality control measurements
(8) Monitor and control project work	I	I	I	I	I	I	I	O	O																			O	O				
(11) Perform integrated change control	I					I	I	I	I											O								O	O	O			
(16) Validate scope	I				O				O	I	I	I	I																O		O		
(17) Control scope	I				O		I		O	I	I		I															O	O			O	
(21) Control schedule	I	O			O		I		O				I	I	I	I												O	O			O	
(23) Control costs	I		O		O		I		O				I				I											O	O			O	
(29) Control quality	I			O	O		I		O			O	I					I	I	I	I	I						O	O			O	O
(32) Control communications	I				O		I		O				I										I	I				O	O			O	
(34) Control risks	I				O			I	O				I												I			O	O			O	
(37) Control procurement	I				O			I	O				I							I						I	I	O	O			O	
(38) Control stakeholder engagement	I				O				O				I									I		I				O	O			O	

A.2. Detailed inputs and outputs of the PRINCE2 project control activities

Table 5. PRINCE2 project control activities: inputs (I) and outputs (O)

Activities	(1) Stage plan	(2) Project initiation documentation	(3) Team plan	(4) Corrective action	(5) New work package	(6) Stage authorization	(7) Exception plan approved	(9) Work package(s)	(10) Checkpoint report(s)	(11) Quality register	(12) Risk register	(14) Completed work package	(15) Configuration item records	(17) Product status account	(18) Issue register	(19) Project board advice	(21) Lessons log	(22) Daily log	(23) Highlight report (previous period)	(25) New risk	(26) New issue	(28) Tolerance threat	(29) Issue report	(32) Update stage plan	(33) Create work package(s)	(34) Update configurations item records	(35) Update quality register	(36) Update risk register	(37) Update issue register	(38) Authority to deliver a work package	(39) Update work package	(40) Project and approaching	(41) Stage boundary approaching	(42) Request for advice	(43) Update lessons log	(44) Update issue report	(45) Create highlight report (current period)	(46) Update daily log	(47) Create issue report	(48) Create exception report	(49) Exception raised
(8) Authorize a work package	I	I	I	I	I	I	I																	O	O	O	O	O	O	O											
(13) Review work packages status	I		I					I	I	I	I													O		O		O	O		O										
(16) Receive complete work packages	I									I		I	I											O		O															
(20) Review the stage status	I	I		I O	O				I	I	I			I	I	I						O		O				O	O			O	O	O	O	O	O				
(24) Report highlights	I	I							I	I	I			I	I		I	I	I																	O					
(27) Capture and examine issues & risks	I	I														O				I	I							O	O								O	O			
(30) Escalate issues and risks	I	I									I				I							I	I					O	O						O				O	O	
(31) Take corrective action	I			I O							I		I		I			I					I	O		O		O	O						O		O				

A.3. Detailed inputs and outputs of the AACE project control processes and sub-processes

Table 6. AACE project control processes and sub-processes: inputs (I) and outputs (O)

Inputs and outputs	(8) Project scope and execution strategy development	(9) Schedule planning and development	(10) Cost estimating and budgeting	(11) Resource planning	(12) Value analysis and engineering	(13) Risk management	(14) Procurement planning	(15) Project control plan implementation	(16) Project cost accounting	(17) Progress and performance measurement	(18) Project performance assessment	(19) Forecasting	(20) Change management	(21) Project historical database management
(15) Project implementation basis	I							I	I	I	I	I	I	I
(16) Asset alternatives	I													
(17) Change information	I													
(18) Defining deliverables	I													
(19) Historical project information	I			I			I	I	I-O	I-O	I-O	I-O	I-O	
(20) Planning process plans	I													
(21) Basis for planning	O													
(22) Basis for asset planning	O	O		O										
(23) Project planning basis		I		I			I							
(24) Work breakdown structure (WBS), work packages, and execution strategy		I												
(25) Technical deliverables		I	I											
(26) Asset alternative scope		I		I										
(27) Historical schedule information		I-O												
(28) Trends, deviations, and changes		I-O												
(29) Estimated costs		I												
(30) Resource quantities		I		I										
(31) Information from project planning		I												
(32) Schedule submittals		I-O												
(33) Refined scope development		O	O											
(34) Information for project planning		O												
(35) Basis for schedule performance measurement and assessment		O												
(36) Scope definition			I									I	O	
(37) Schedule information			I											
(38) WBS			I											
(39) Chart of accounts			I	I			I							
(40) Historical cost information			I											
(41) Estimate information			I-O											
(42) Cost control baseline			O											
(43) Resource requirements			O											
(44) Cost information for analyses			O											
(45) Estimate basis			O											
(46) Refined plan and schedule			O											
(47) Changes				I			I	I	I	I	I			
(48) Resource expenditure information				I										

Inputs and outputs	(8) Project scope and execution strategy development	(9) Schedule planning and development	(10) Cost estimating and budgeting	(11) Resource planning	(12) Value analysis and engineering	(13) Risk management	(14) Procurement planning	(15) Project control plan implementation	(16) Project cost accounting	(17) Progress and performance measurement	(18) Project performance assessment	(19) Forecasting	(20) Change management	(21) Project historical database management
(49) Organizational breakdown structure (OBS)				I										
(50) Execution strategy				I			I-O	I						
(51) Societal values and performance considerations				I										
(52) Information for analysis				I			I							
(53) Resource quantity availability and limitations				O										
(54) Basis for project control plans and plan implementation				O										
(55) Strategic asset requirements and project implementation basis					I	I								
(56) Asset or project scope					I	I								
(57) Asset or project technical information					I									
(58) Customer requirements					I									
(59) Planning information					I-O	I		I-O				I-O		
(60) Cost information					I-O									
(61) Historical information					I-O	I-O								
(62) Value study report					O									
(63) Cost, schedule, and resource information						I-O								
(64) Risk performance assessment						I								
(65) Change information and contingency management						I-O								
(66) Planning basis information						O								
(67) Risk management plan						O					I-O			
(68) Basis for project control							I-O	O						
(69) Estimate and schedule information							I-O							
(70) Contract requirements for project control							O							
(71) WBS, OBS, and work packages								I-O						
(72) Validation metrics								I						
(73) Project control plan and control accounts									I-O	I-O				
(74) Progress measurement plans									I-O					
(75) Work progress									I					
(76) Charges to project accounts									I					
(77) Corrections to charges									O					
(78) Cost information for financing									O					
(79) Cost information for capitalization									O					
(80) Cost information for control									O					
(81) Project cost accounting plans										I-O				
(82) Work, resource, and process performance										I				
(83) Corrections to measurement basis										O				
(84) Information for enterprise resource planning										O				
(85) Measurement information for project cost accounting										O				
(86) Measurement information for performance assessment										O				
(87) Status information for change management										O				
(88) Project control plan											I-O	I-O	I-O	I-O
(89) Performance measurement plans											I-O			
(90) Project control basis											I-O	I-O	O	

Inputs and outputs	(8) Project scope and execution strategy development	(9) Schedule planning and development	(10) Cost estimating and budgeting	(11) Resource planning	(12) Value analysis and engineering	(13) Risk management	(14) Procurement planning	(15) Project control plan implementation	(16) Project cost accounting	(17) Progress and performance measurement	(18) Project performance assessment	(19) Forecasting	(20) Change management	(21) Project historical database management
(91) Performance measures and observations											I			
(92) Information for forecasting											O			
(93) Information for project change management											O			
(94) Scope of changes												I		
(95) Physical progress												I		
(96) Trends												I	O	
(97) Corrective actions												I		
(98) Approved scope												I		
(99) Corrective action alternatives												O	I-O	
(100) Alternative forecasts												O	I-O	
(101) Deviation, notices, and change requests													I	
(102) Variances													I	
(103) Risk management information													I	
(104) Procurement information													I	
(105) Selected corrective actions and approved scope													O	
(106) Control baseline data														I
(107) Actual performance data														I
(108) Performance and methods and tools experiences														I
(109) Project system and external information														I
(110) Planning reference data														O
(111) Plan validation data														O
(112) Data to support methods and tools development														O
(113) Information for project system management														O

Appendix B. Centrality measures

B.1. PMBOK network centrality measures

Table 7. Centrality measures for the PMBOK network

No.	Processes, inputs, and outputs	In-degree	Out-degree	Betweenness	Closeness
1	Project management plan	0	**0.256**	0	0.052
2	Schedule forecasts	0.023	0.023	0.008	0.037
3	Cost forecasts	0.023	0.023	0.004	0.037
4	Validated changes	0.023	0.023	0.013	0.036
5	Work performance information	**0.209**	0.023	0.085	0.035
6	Enterprise environmental factors	0	0.047	0	0.037
7	Organizational process assets	0	**0.163**	0	0.049
8	Monitor and control project work	**0.163**	0.093	**0.161**	0.036
9	Work performance reports	0.023	0.070	0.094	0.036

No.	Processes, inputs, and outputs	In-degree	Out-degree	Betweenness	Closeness
10	Change requests	**0.233**	0.023	**0.248**	0.036
11	Perform integrated change control	0.116	0.093	**0.282**	0.036
12	Requirements documentation	0	0.047	0	0.038
13	Requirements traceability matrix	0	0.047	0	0.038
14	Verified deliverables	0.023	0.023	0.071	0.036
15	Work performance data	0.000	**0.209**	0	0.051
16	Validate scope	0.116	0.093	0.074	0.036
17	Control scope	0.116	0.116	0.023	0.037
18	Project schedule	0	0.023	0	0.039
19	Project calendars	0	0.023	0	0.039
20	Schedule data	0	0.023	0	0.039
21	Control schedule	0.140	0.140	0.069	0.039
22	Project funding requirements	0.000	0.023	0	0.039
23	Control costs	0.093	0.140	0.027	0.039
24	Quality metrics	0	0.023	0	0.037
25	Quality checklists	0	0.023	0	0.037
26	Approved change requests	0.023	0.047	**0.210**	0.036
27	Deliverables	0	0.023	0	0.037
28	Project documents	0	0.047	0	0.039
29	Control quality	**0.186**	**0.186**	**0.254**	0.037
30	Project communications	0	0.023	0	0.038
31	Issue log	0	0.047	0	0.039
32	Control communications	0.116	0.116	0.033	0.037
33	Risk register	0	0.023	0	0.037
34	Control risks	0.093	0.116	0.030	0.036
35	Procurement documents	0	0.023	0	0.037
36	Agreements	0	0.023	0	0.037
37	Control procurements	0.140	0.116	0.060	0.036
38	Control stakeholder engagement	0.093	0.116	0.018	0.037
39	Project management plan updates	**0.233**	0	0	0.023
40	Project documents updates	**0.256**	0	0	0.023
41	Change log	0.023	0	0	0.023
42	Accepted deliverables	0.023	0	0	0.023
43	Organizational process assets updates	**0.186**	0	0	0.023
44	Quality control measurements	0.023	0	0	0.023

B.2. PRINCE2 network centrality measures

Table 8. Centrality measures for the PRINCE2 network

No.	Processes, inputs, and outputs	In-degree	Out-degree	Betweenness	Closeness
1	Stage plan	0	**0.167**	0	0.051
2	Project initiation documentation	0	0.104	0	0.044
3	Team plan	0	0.042	0	0.026
4	Corrective action	0.042	0.063	0.082	0.035
5	New work package	0.021	0.021	0.018	0.024
6	Stage authorization	0	0.021	0	0.024
7	Exception plan approved	0	0.021	0	0.024
8	Authorize a work package	0.146	0.146	0.076	0.024
9	Work package(s)	0	0.021	0	0.023
10	Checkpoint report(s)	0	0.063	0	0.042
11	Quality register	0	0.083	0	0.044
12	Risk register	0	0.104	0	0.042
13	Review work packages status	0.125	0.104	0.016	0.023
14	Completed work package	0	0.021	0	0.022
15	Configuration item records	0	0.042	0	0.037
16	Receive complete work packages	0.083	0.042	0.004	0.021
17	Product status account	0	0.042	0	0.039
18	Issue register	0	0.083	0	0.039
19	Project board advice	0.021	0.021	0.051	0.036
20	Review the stage status	**0.188**	**0.229**	**0.190**	0.035
21	Lessons log	0	0.021	0	0.021
22	Daily log	0	0.042	0	0.038
23	Highlight report (previous period)	0	0.021	0	0.021
24	Report highlights	**0.208**	0.021	0.009	0.021
25	New risk	0	0.021	0	0.039
26	New issue	0	0.021	0	0.039
27	Capture and examine issues & risks	0.083	0.104	0.048	0.038
28	Tolerance threat	0.021	0.021	0.032	0.023
29	Issue report	0	0.042	0	0.036
30	Escalate issues and risks	0.125	0.104	0.039	0.023
31	Take corrective action	0.146	0.146	0.070	0.035
32	Update stage plan	0.104	0	0	0.020
33	Create work package(s)	0.021	0	0	0.020
34	Update configurations item records	0.083	0	0	0.020
35	Update quality register	0.021	0	0	0.020
36	Update risk register	0.125	0	0	0.020
37	Update issue register	0.125	0	0	0.020
38	Authority to deliver a work package	0.021	0	0	0.020
39	Update work package	0.021	0	0	0.020
40	Project and approaching	0.021	0	0	0.020
41	Stage boundary approaching	0.021	0	0	0.020
42	Request for advice	0.021	0	0	0.020
43	Update lessons log	0.021	0	0	0.020
44	Update issue report	0.063	0	0	0.020
45	Create highlight report (current period)	0.021	0	0	0.020
46	Update daily log	0.042	0	0	0.020

No.	Processes, inputs, and outputs	In-degree	Out-degree	Betweenness	Closeness
47	Create issue report	0.021	0	0	0.020
48	Create exception report	0.021	0	0	0.020
49	Exception raised	0.021	0	0	0.020

B.3. AACE network centrality measures

Table 9. Centrality measures for the AACE network

No.	Processes, inputs, and outputs	In-degree	Out-degree	Betweenness	Closeness
1	Project scope and execution strategy development	0.054	0.018	0.015	0.009
2	Schedule planning and development	0.089	0.063	0.010	0.009
3	Cost estimating and budgeting	0.063	0.063	0.071	0.009
4	Resource planning	0.098	0.027	0.026	0.009
5	Value analysis and engineering	0.063	0.036	0.069	0.019
6	Risk management	0.063	0.045	0.077	0.019
7	Procurement planning	0.071	0.036	0.076	0.019
8	Project control plan implementation	0.063	0.027	0.106	0.019
9	Project cost accounting	0.063	0.063	0.083	0.020
10	Progress and performance measurement	0.054	0.071	0.082	0.020
11	Project performance assessment	0.071	0.063	0.120	0.020
12	Forecasting	0.098	0.054	**0.227**	0.020
13	Change management	0.080	0.071	**0.164**	0.020
14	Project historical database management	0.054	0.045	0.075	0.019
15	Project implementation basis	0	0.071	0	0.020
16	Asset alternatives	0	0.009	0	0.009
17	Change information	0	0.009	0	0.009
18	Defining deliverables	0	0.009	0	0.009
19	Historical project information	0.045	0.080	**0.282**	0.020
20	Planning process plans	0	0.009	0	0.009
21	Basis for planning	0.009	0	0	0.009
22	Basis for asset planning	0.027	0	0	0.009
23	Project planning basis	0	0.027	0	0.022
24	WBS, work packages, and execution strategy	0	0.009	0	0.010
25	Technical deliverables	0	0.018	0	0.010
26	Asset alternative scope	0	0.018	0	0.010
27	Historical schedule information	0.009	0.009	0	0.009
28	Trends, deviations, and changes	0.009	0.009	0	0.009
29	Estimated costs	0	0.009	0	0.010
30	Resource quantities	0	0.018	0	0.010
31	Information from project planning	0	0.009	0	0.010
32	Schedule submittals	0.009	0.009	0	0.009
33	Refined scope development	0.018	0	0	0.009
34	Information for project planning	0.009	0	0	0.009
35	Basis for schedule performance measurement and assessment	0.009	0	0	0.009
36	Scope definition	0.009	0.018	0.074	0.019
37	Schedule information	0	0.009	0	0.010
38	WBS	0	0.009	0	0.010
39	Chart of accounts	0	0.027	0	0.019
40	Historical cost information	0	0.009	0	0.010
41	Estimate information	0.009	0.009	0	0.009

No.	Processes, inputs, and outputs	In-degree	Out-degree	Betweenness	Closeness
42	Cost control baseline	0.009	0	0	0.009
43	Resource requirements	0.009	0	0	0.009
44	Cost information for analyses	0.009	0	0	0.009
45	Estimate basis	0.009	0	0	0.009
46	Refined plan and schedule	0.009	0	0	0.009
47	Changes	0	0.054	0	0.020
48	Resource expenditure information	0	0.009	0	0.009
49	OBS	0	0.009	0	0.009
50	Execution strategy	0.009	0.027	0.054	0.019
51	Societal values and performance considerations	0	0.009	0	0.009
52	Information for analysis	0	0.018	0	0.019
53	Resource quantity availability and limitations	0.009	0	0	0.009
54	Basis for project control plans and plan implementation	0.009	0	0	0.009
55	Strategic asset requirements and project implementation basis	0	0.018	0	0.019
56	Asset or project scope	0	0.018	0	0.019
57	Asset or project technical information	0	0.009	0	0.019
58	Customer requirements	0	0.009	0	0.019
59	Planning information	0.027	0.036	**0.184**	0.019
60	Cost information	0.009	0.009	0	0.019
61	Historical information	0.018	0.018	0.006	0.019
62	Value study report	0.009	0	0	0.009
63	Cost, schedule, and resource information	0.009	0.009	0	0.019
64	Risk performance assessment	0	0.009	0	0.019
65	Change information and contingency management	0.009	0.009	0	0.019
66	Planning basis information	0.009	0	0	0.009
67	Risk management plan	0.018	0.009	0.048	0.019
68	Basis for project control	0.018	0.009	0.005	0.019
69	Estimate and schedule information	0.009	0.009	0	0.019
70	Contract requirements for project control	0.009	0	0	0.009
71	WBS, OBS, and work packages	0.009	0.009	0	0.019
72	Validation metrics	0	0.009	0	0.019
73	Project control plan and control accounts	0.018	0.018	0.004	0.019
74	Progress measurement plans	0.009	0.009	0	0.019
75	Work progress	0	0.009	0	0.020
76	Charges to project accounts	0	0.009	0	0.020
77	Corrections to charges	0.009	0	0	0.009
78	Cost information for financing	0.009	0	0	0.009
79	Cost information for capitalization	0.009	0	0	0.009
80	Cost information for control	0.009	0	0	0.009
81	Project cost accounting plans	0.009	0.009	0	0.019
82	Work, resource, and process performance	0	0.009	0	0.020
83	Corrections to measurement basis	0.009	0	0	0.009
84	Information for enterprise resource planning	0.009	0	0	0.009
85	Measurement information for project cost accounting	0.009	0	0	0.009
86	Measurement information for performance assessment	0.009	0	0	0.009
87	Status information for change management	0.009	0	0	0.009
88	Project control plan	0.036	0.036	0.119	0.020
89	Performance measurement plans	0.009	0.009	0	0.019
90	Project control basis	0.027	0.018	0.010	0.019
91	Performance measures and observations	0	0.009	0	0.020

No.	Processes, inputs, and outputs	In-degree	Out-degree	Betweenness	Closeness
92	Information for forecasting	0.009	0	0	0.009
93	Information for project change management	0.009	0	0	0.009
94	Scope of changes	0	0.009	0	0.020
95	Physical progress	0	0.009	0	0.020
96	Trends	0.009	0.009	0.002	0.019
97	Corrective actions	0	0.009	0	0.020
98	Approved scope	0	0.009	0	0.020
99	Corrective action alternatives	0.018	0.009	0.011	0.019
100	Alternative forecasts	0.018	0.009	0.011	0.019
101	Deviation notices and change requests	0	0.009	0	0.020
102	Variances	0	0.009	0	0.020
103	Risk management information	0	0.009	0	0.020
104	Procurement information	0	0.009	0	0.020
105	Selected corrective actions and approved scope	0.009	0	0	0.009
106	Control baseline data	0	0.009	0	0.020
107	Actual performance data	0	0.009	0	0.020
108	Performance and methods and tools experiences	0	0.009	0	0.020
109	Project system and external information	0	0.009	0	0.020
110	Planning reference data	0.009	0	0	0.009
111	Plan validation data	0.009	0	0	0.009
112	Data to support methods and tools development	0.009	0	0	0.009
113	Information for project system management	0.009	0	0	0.009

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Business process models and entity life cycles

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Abstract:
Tasks and business entities are the major constituents of business processes but they are not always considered equally important. The activity-centric approach and the artifact-oriented one have radically different visions. The former focuses on the control flow, i.e., on the representation of the precedence constraints between tasks, and considers the dataflow an add-on. The latter emphasizes the states of the business entities and defines the transitions between states in a declarative way that makes it difficult to figure out what the control flow is. This paper presents the ELBA notation whose purpose is to integrate those different visions by leveraging the dataflow. The dataflow defines the input and output entities of the tasks in process models. Entities flowing through tasks change their states and then a process model results from the combination of the life cycles of the entities managed by the process. Process models are complemented by information models that show the attributes and relationships of the entity types handled by the processes. Life cycles are intertwined in process models but they can be separated by means of an extraction technique that is illustrated in this paper with the help of two examples.

Keywords:
business processes; control flow; dataflow; artifact; entity life cycle.

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1. Introduction

Business processes are made up of tasks that are usually meant to operate on persistent business entities, but, unfortunately, these two elements, tasks and entities, are not given the same level of importance in the current notations for business process modeling. In BPMN (Business Process Model and Notation) [1], business entities are denoted by variables in process instances and can optionally be shown in process models by means of graphical elements called data objects.

BPMN is an activity-centric notation: the control flow organizes the execution of tasks in a predefined manner. Tasks are divided into automatic tasks and human ones. Human tasks are associated with roles and are performed by persons playing the roles required; however, they have little influence on the evolution of the process and are mainly involved in tasks that are not easy to automate. BPMN fits repetitive situations, i.e., routines, and provides an efficient way to handle them.

While BPMN puts tasks before business entities, the opposite takes place with GSM (Guard-Stage-Milestone) [2]. GSM emphasizes that business entities evolve over time through life cycles made up of states (also called stages); tasks are included in stages. The overall process is a collection of interacting life cycles.

Knowledge-intensive processes [3] focus on individual cases and rely on the expertise of participants to find the best way to handle them. Flexibility is the major issue and, then, a declarative approach to business process modeling is preferred to the traditional procedural one. In GSM, stages are activated and closed by means of ECA (Event Condition Action) rules [4] and this confers great flexibility to the approach. CMMN (Case Management Model and Notation) [5] draws on GSM and provides process participants with the flexibility of deciding the activities to be carried out; moreover, participants can assign tasks to each other. BPMN provides some flexibility with the ad-hoc construct: a comparison with CMMN can be found in Zensen and Küster [6].

What is missing in the above-mentioned approaches is the explicit representation of the dataflow, which defines the input and output entities of the tasks in process models. Entities flowing through tasks change their states: states indirectly represent the processing performed by tasks on entities. A process then combines the life cycles of the entities involved.

This paper presents a notation, called ELBA, which addresses the above issues. Life cycles are intertwined in process models but they can be separated by means of an extraction technique. Since a life cycle emphasizes the evolution over time of an entity type its model may be important for a comparison with industry standards or with the expectations of stakeholders.

The extraction of life cycles is challenging for two reasons: one is their intertwining in process models, and the other is due to hidden states. Hidden states are states that do not explicitly appear in process models because the presence of entities in these states is not an event for the process. Such states might be ignored; however, if they are considered important, they can be made explicit so the extraction algorithm will show them in life cycle models.

This paper is organized as follows. Section 2 is about the related work. Section 3 introduces ELBA and shows how life cycles can be extracted from a simple process model. Section 4 concerns the handling of hidden states. Section 5 contains the conclusion.

2. Background

Most of the notations for business process modeling fall in three categories based on the predominant aspect: the control flow, the dataflow and the entity life cycles.

The activity-centric notations, such as UML (Unified Modeling Language) [7] activity diagrams and BPMN, focus on the control flow, whose purpose is to define precedence constraints between tasks by means of direct links or through the intermediation of control flow elements (called gateways in BPMN). This approach provides an efficient way to

deal with repetitive situations, i.e., routines. The dataflow may be added to the above mentioned notations but in a way that Sanz [8] judges as an "afterthought". The control flow and the dataflow are separate and this makes the notation more complicated.

Combi et al. [9] present an extension to BPMN whose purpose is to link tasks to data: the extension consists in textual annotations that describe the operations performed by tasks on data stored in a database. Moreover, the attributes and relationships of the data are modeled with a UML class diagram.

Another kind of extension is aimed at associating resources (i.e., IoT devices) to BPMN tasks. For example, Martins and Domingos [10] show how to translate a BPMN model into a programming language for IoT devices.

The artifact-oriented approach shifts the focus from tasks to business entities. It does so by introducing the notion of artifact, which, in this context, represents an entity type and the life cycle of its entities. Artifacts designate concrete and self-describing chunks of information used to run a business [11]; moreover, they facilitate communication among stakeholders and help them focus on the primary purposes of the business [12].

The notation provided by GSM focuses on the life cycles of artifacts: they are separate and are made up of stages, which may include subordinate stages and tasks. Stages are provided with guards and milestones, which consist of ECA rules. When a guard becomes true, the stage is activated; the stage is closed, when a milestone becomes true. The event that causes the opening of a stage may come from a stage of another artifact. This mechanism confers great flexibility to the approach, but its major drawback is the difficulty of understanding the precedence between the stages. The control flow between stages is not shown; moreover, the dataflow is missing because the life cycles are separate.

In PHILharmonicFlows [13], the entity life cycles are represented with state-transition diagrams (called micro processes), and then the precedence constraints between stages are clearly shown. Since life cycles are separate the notation introduces a coordination mechanism (called macro process) to orchestrate their evolution: this entails the repetition of several stages in the macro process. However, not all the stages are repeated in the macro process; therefore, the observation of all the models is needed to fully understand the overall process.

Life cycles may be extracted from notations that provide the representation of the dataflow. Extraction approaches have been proposed for UML Activity Diagrams ([14], [15], [16]) as well as for BPMN models [17].

The recent case management standard CMMN stresses the abilities of case workers to decide the order of execution of tasks and to assign tasks to each other. It draws on GSM in that processes are made up of stages that are groups of tasks: the opening and closing of stages are based on events, such as the completion of a task, a time event or a human decision. However, the stages are not related to the life cycles of the business entities and, moreover, the dataflow is missing.

If the control flow and the dataflow are integrated, the tasks in the process turn out to be data-driven: they are performed when their inputs contain suitable entities.

In the case handling approach [18], tasks are data driven but the dataflow is not shown because the process data are kept in process variables; however, the process includes the links between the tasks and the variables that provide their inputs.

Two frameworks have been proposed to compare notations on the basis of their data modeling capabilities. The first framework [19] focuses on the representation of the dataflow and of the life cycles of the entities that make it up. As to BPMN and UML activity diagrams, the authors conclude that data modeling is optional and when the dataflow is shown it is subordinate to the control flow.

The second framework [20] is used to compare notations for business process modeling on the basis of 24 criteria subdivided in four groups: design, implementation and execution, diagnosis and optimization, tool implementation and practical cases. The authors compared three notations, i.e., case handling, GSM and PHILharmonicFlows. The conclusion is that most practitioners consider data-centric notations more complicated than activity-centric ones and therefore data-centric approaches need further research.

The ELBA notation provides a solution giving equal importance to tasks and business entities. Tasks are data driven and the dataflow is explicitly shown. The dataflow consists of entity states and the entity types along with their attributes and relationships are defined in an information model, similar to a UML class diagram. The entity life cycles are intertwined in the dataflow but they can be separated as illustrated in the next sections.

Data resides in the entities forming the dataflow: a process is implemented with a single instance and therefore it is easy to decompose and recompose entity flows. As a consequence, situations like the many-to-many mapping between requisition orders and procurement ones in build-to-order processes, which are difficult to handle with BPMN as pointed out in Meyer et al. [21], can be easily addressed with ELBA [22].

As to flexibility, ELBA [23] addresses human decisions that concern the selection of input entities when a task needs more than one, or the selection of the task when more than one are admissible to handle the input entities.

3. Introduction to ELBA

The main feature of ELBA is that a process model results from the combination of the life cycles of the entities managed by the process. The definition of the entities takes place through an information model that shows the entity types along with their attributes and relationships. In addition, ELBA is a dataflow language in that the activation of tasks is based on the input entities and not on the completion of previous tasks.

An ELBA process comes with a single instance: this implies that the entities handled by a process are not internal to the process but external to it. Entities are assumed to reside in an information system that guarantees their persistence.

A process model actually consists of two models: one is the information model that shows the domain related to the process and the other is the actual process from which the separate life cycles of the managed entities can be extracted.

This section presents a simple example to explain the basic features of the notation. The example concerns process CheckProposals, which operates in an organization that receives proposals from partners: the process checks the proposals with the help of a number of reviewers.

The simplified requirements of the process are as follows. Partners and reviewers are registered in the information system. The relations between the partners and the organization are managed by persons playing the account manager (shortly, accountMgr) role: each partner is associated with one account manager who can deal with a number of partners. After a proposal has been entered by a partner, the process hands it to the suitable account manager, who selects three reviewers and associates them with the proposal. Each reviewer is required to submit a review and, when all the three reviews are available, the account manager decides whether to accept or reject the proposal. Then, the partner is notified of the outcome. The attributes of the entities are kept to a minimum: a proposal has a description and an outcome (which initially is null and then becomes accepted or rejected), and a review has a comment. The process model and the information one are shown in Fig. 1.

The information model draws on the UML class diagram and adds a number of features such as required properties, rules, and indirect relationships.

Entity types may be divided into three groups: role types, managed types and background ones. A role type denotes the process participants playing the role that it represents. For example, role type Reviewer denotes all the persons acting as reviewers and an instance of it denotes a specific reviewer. Instances of role types are referred to as role entities.

Managed types, such as Proposal and Review, are the types of the entities forming the dataflow of the process. Background types denote entities that provide background information: the process does not generate background entities but may introduce associations between managed entities and background ones. In the example under consideration, there are no background entities.

Relationships show the constraints on the number of associations between entities and they do so by means of multiplicity indicators. Indicators include integer values as well as symbols “n” and “*” which mean one or more associations, and zero or more associations, respectively. The standard multiplicity is “*”.

Required properties encompass required attributes and required associations. The former are recognizable by the names underlined and the latter by the multiplicities underlined. Required properties must be set when new entities are generated. For example, a new proposal is linked to the partner who entered it; moreover, a new review is connected to the reviewer who provided it and to the proposal it is related to.

Indirect relationships are sequences of direct relationships. An example is given by the indirect relationship between Proposal and AccountMgr: a proposal is indirectly linked to an account manager through the association with a partner, and an account manager is indirectly linked to the proposals of the partners he or she is associated with.

Rules will be explained in the next section.

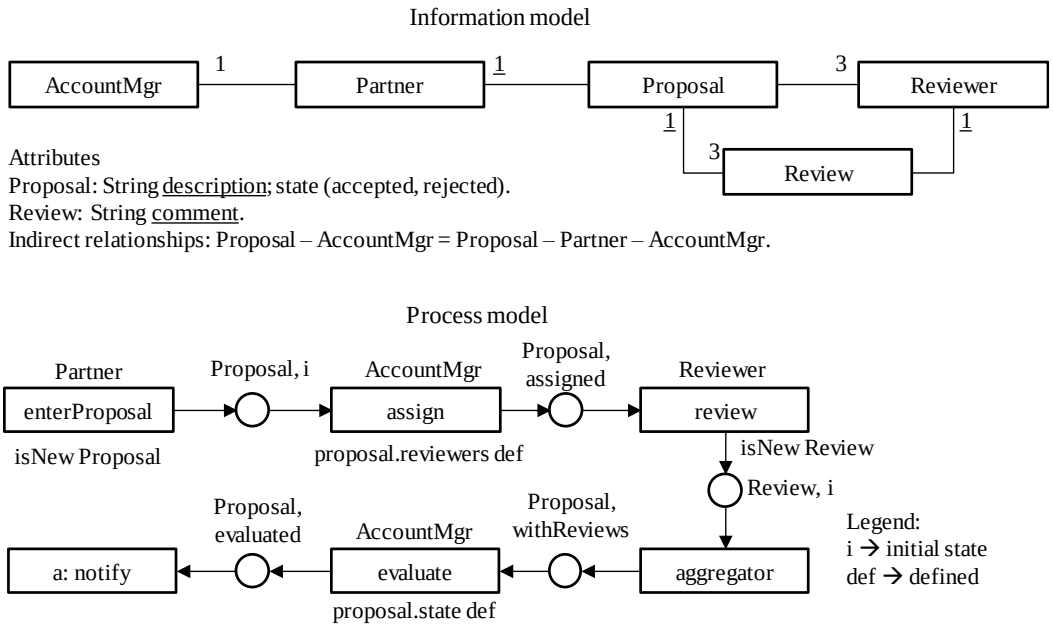


Fig. 1. The model of process CheckProposals and the related information model

A process model is a connected bipartite graph made up of tasks and entity states. The symbols of tasks and entity states are the rectangle and the circle, respectively. Tasks and entity states are connected by means of oriented arcs that establish input and output associations between them. The structure of ELBA processes has been inspired by Petri nets [24]: entity states correspond to places and tasks correspond to transitions.

Entity states have labels consisting of two parts: the entity type, which matches a managed type appearing in the information model, and the state name. The states indicate the progress of the entities in their life cycles.

The analysis of the input and output states of tasks leads to the identification of various kinds of tasks, the most frequent of which are entry tasks, exit tasks, transitional tasks and mapping ones. An entry task has no inputs: its purpose is to introduce new entities in a process. An exit task has no outputs in that it removes the input entities from the process.

In a transitional task the input and output entities have the same type. When the task is completed the input entities are moved into the output states and, therefore, they undergo a change of state. A mapping task has one input state and one output state whose types are different, say, T1 and T2. The effect of the task is to map an input entity into a number of

output entities: the output entities are those associated with the input one on the basis of the relationship between types T1 and T2.

Tasks are divided into automatic tasks and human ones. The former are told apart because their names are preceded by "a:" and the latter are accompanied by the role of the performers (which is shown next to the task symbol). Tasks have a number of features, i.e., pre-conditions, post-conditions, and assignment rules. Pre-conditions and post-conditions are boolean expressions based on the input entities and draw on OCL (Object Constraint Language) [25]. In a declarative manner, the former express the conditions required for the execution of the tasks and the latter define the effects produced on the underlying information system.

A human task is carried out by a process participant playing the role required by the task. The determination of the actual performer can be established by means of rules. ELBA provides two standard rules. The first rule concerns tasks having no inputs: any person playing the role required by the task is entitled to perform it. In the other cases, the second rule is applied. It assumes that the input entities of a task are associated with one or more role entities whose types match the role required by the task. Since role entities denote process participants, the associations between input entities and role entities determine the process participants who can operate on the input entities by performing the task. The standard rules can be replaced by specific assignment rules; in the examples, there are no exceptions to the standard rules.

The process model shown in Fig. 1 is made up of six tasks and five entity states. The post-conditions are shown below the corresponding tasks.

The first task, enterProposal, is an entry task in that it has no inputs; any partner can perform it. The purpose of the task is to enter a new Proposal in the process, as shown by the post-condition "isNew Proposal". The effect of the execution of the task is the presence of a new proposal in the information system. From the dataflow point of view, the new proposal is put into the output state of the task because the type of the output state matches the type of the new entity. This state is the initial state of proposals. By convention, the name of any initial state is "i" (the first character of initial).

If the type, say, T1, of a new entity is subject to a required relationship with type, say, T2, then the new entity must be associated with a T2 entity. This association can be carried out automatically if a T2 entity is found in the contextual entities of the task that brought the new entity into existence. The contextual entities of a task consist of the performer (in case of a human task) and the input entities. Since there is a required relationship from type Proposal to type Partner, a new proposal must be associated with a partner. Task enterProposal has one contextual entity, the performer of the task, whose type is Partner; therefore the performer is automatically connected to the new proposal.

The second task, assign, enables an account manager to assign the proposal to three reviewers, as shown by post-condition "proposal.reviewers def". The number of reviewers is taken from the multiplicity of the relationship Proposal – Reviewer. Due to the indirect relationship Proposal – AccountMgr defined in the information model, the account manager who is entitled to operate on the proposal is the one associated with the partner that has entered the proposal.

The purpose of task assign is to associate the proposal with three reviewers selected by the performer. The choice can be based on various criteria such as the load balancing of the reviewers, but, from a declarative perspective, the effect is that the proposal turns out to be linked to three reviewers. The construct "proposal.reviewers" denotes the collection of the reviewers associated with the proposal. It is a navigational expression in which "proposal" represents the input entity: the input entity is referred to by means of its type name with the initial in lower case. The dot between proposal and reviewers shifts the focus from the proposal to the reviewers. Term "reviewers" is an associative attribute whose name is taken from type Reviewer: since the multiplicity of the associative attribute is greater than one, the plural of the type name with the initial in lower case is used. The effect of the post-condition "proposal.reviewers def", where def is the abbreviation of "defined", implies that the collection of reviewers, which initially is empty, will not be empty at the end of the task. On the basis of multiplicity 3 of the relationship from Proposal to Reviewer, the collection will refer to three reviewers. Task assign is a transitional task in that it has an input state and an output one of the same type: the input proposal is then moved into state assigned.

Task review enables the reviewers of a proposal to produce reviews for it as shown by the post-condition “isNew Review”. A proposal is linked to three reviewers as shown by relationship Proposal – Reviewer; then all the reviewers of a proposal get the same proposal but each of them provides a different review. Due to the required relationships Review – Proposal and Review – Reviewer, each review is automatically connected to the input proposal and to the task performer (a reviewer).

At the end of each execution of task review, a new review enters the output state, which is the initial state of reviews. The process does not handle the reviews individually but deals with the proposal when all the reviews are available. In such cases, ELBA uses an automatic task called aggregator, whose requirements are as follows. The aggregator has one input state and one output state whose types (say, T1 and T2) are different but interrelated: the input type (T1) and the output one (T2) participate in a relationship with multiplicity many to one. When all the entities T1 related to the same entity T2 are present in the input state, the aggregator removes them and outputs the entity T2. Therefore, the aggregator shown in Fig. 1 puts a proposal into the output state when its reviews are available in the input state. Three reviews are needed on the basis of the multiplicity of type Review with respect to type Proposal in the information model.

Task evaluate is a transitional task because the input entities and the output ones have the same type. From the dataflow point of view, the effect is a change of state of the input entities. The effect on the input proposal is a modification of the outcome attribute as shown by the post-condition “proposal.outcome def”. The performer decides the value of the outcome, which initially is null, by selecting one of the two values, accepted or rejected, specified in the information model.

The last task, notify, is an automatic task which notifies the outcome of the proposal to the partner. It is an exit task in that it removes the input entity from the process. The post-condition is omitted because it has no impact on the information system.

The process model is a combination of different life cycles which are intertwined, but it can be useful to show them separately. The extraction of the life cycles is carried out with a simple algorithm as follows. The algorithm assumes that the resulting life cycles are sequential state models; therefore concurrent states are not handled.

The algorithm is informally explained with reference to the process model shown in Fig. 1. Firstly, it adds output states to exit tasks and aggregators. The output states added to an exit task have the same type as the input ones and their name is “final”. The algorithm may add a new output state to an aggregator: the new state has the same type as the input state of the aggregator and its name is “final”. The addition is made only if there are no other states of the same type in the outgoing paths of the aggregator. If there are other states, the life cycle of the input entities continues after the aggregator. The changes made to the process model by the algorithm are shown in Fig. 2.

For each managed type, say, T, the algorithm generates a life cycle graph whose nodes correspond to the states of type T in the process. The names of the nodes are the names of the states. For each node, say, N, of the graph, it determines the immediate successors and links node N to them: the successors are obtained by following the paths starting from the state corresponding to node N in the process model. For type Proposal, the graph is a linear sequence of nodes as shown in Fig. 2; likewise for type Review.

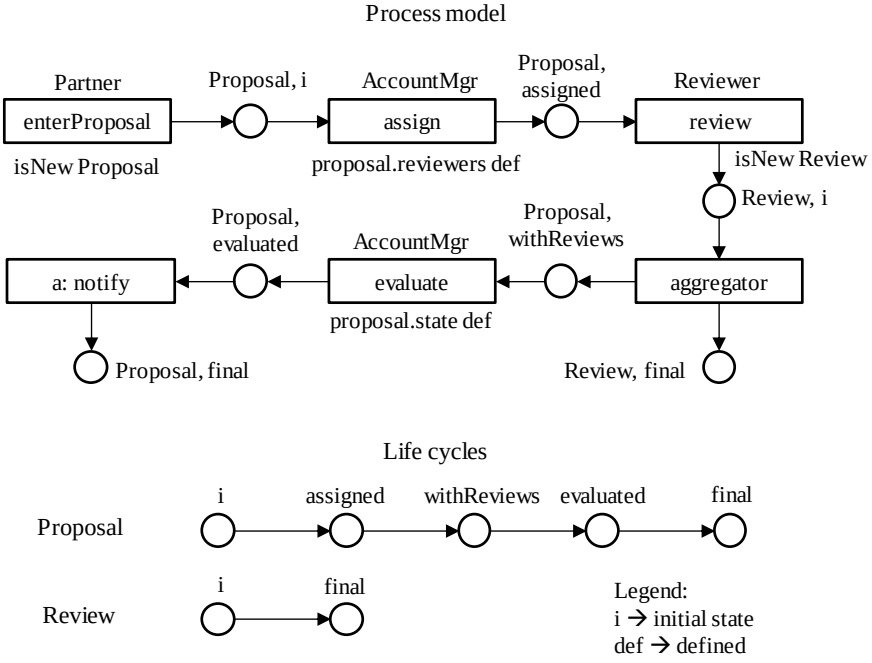


Fig. 2. The modified model of process CheckProposals and the life cycles extracted

4. Hidden states

The entity states that appear in a process model show the dataflow of the process; however, it may happen that certain states that are considered important to describe an entity life cycle do not explicitly appear in the process model because the presence of entities in these states does not bring about the activation of tasks. In such cases, these states, which are referred to as hidden states, may be made visible so that the algorithm that extracts the entity life cycles from the process model can include them. The example illustrated in this section explains how to make visible the hidden states.

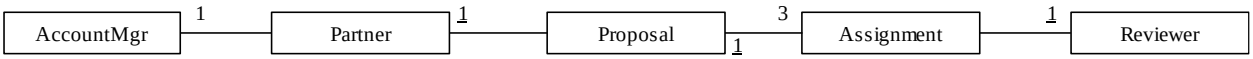
The example is a variant of process CheckProposals illustrated in the previous section; the variant is named CheckProposals2. The difference is that account managers do not directly associate reviewers with proposals but generate three assignments for each proposal; an assignment is connected exactly to one proposal and one reviewer. Reviewers fulfill their assignments and when all the expected assignments for a proposal have been fulfilled, the account manager can decide the outcome of the proposal. The information model of the process is shown in Fig. 3, while the process model and the entity life cycles are presented in Fig. 4.

The annotations of the information model include a rule prescribing that a proposal must be assigned to different reviewers. The rule is based on the navigational expression “proposal.assignments.reviewer”, where the first term, proposal, stands for any proposal. For any proposal, the collection of reviewers related to the assignments associated with the proposal must contain different elements.

Unlike the first process model, task assign is not a transitional task because the types of its input and output entities are different. It is instead a mapping task as it maps a proposal into three assignments.

The effect of task assign is the presence of three new assignments after its execution. The number of assignments is indicated between parentheses in the post-condition. The required relationships of type Assignment imply that a new assignment must be linked to a proposal and a reviewer. The contextual entities of task assign are the input proposal and the performer. The input proposal is automatically associated with the new assignment. Since no reviewer is found in

the contextual entities of the task, the reviewer is selected by the performer of the task during its execution. Rule 1 (included in the information model) guarantees that the new assignments are linked to distinct reviewers. The output state of the task is the initial state of the entities of type Assignment.



Attributes
Proposal: String description; outcome (accepted, rejected).
Assignment: String review.
Indirect relationships: Proposal – AccountMgr = Proposal – Partner – AccountMgr.
Rule 1: proposal.assignments.reviewer distinct

Fig. 3. The information model of process CheckProposals2

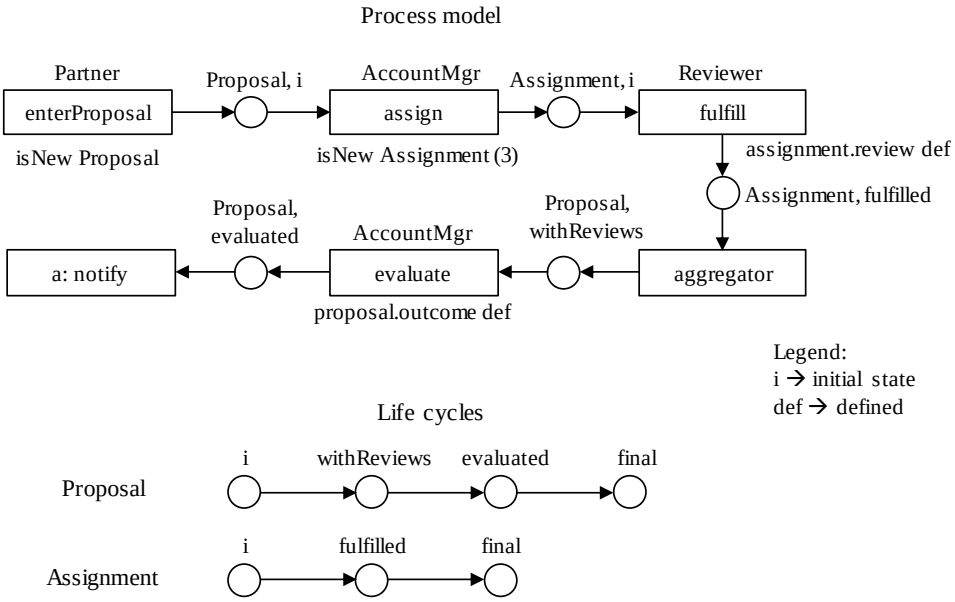


Fig. 4. The model of process CheckProposals2 and the entity life cycles extracted

The name (withReviews) of the output state of the aggregator indicates that the assignments associated with the proposal contain the reviews provided by the reviewers.

The Proposal life cycles extracted from processes CheckProposals and CheckProposals2 are different. The second life cycle has one state (assigned) less than the first one. The reason for this is that task assign is a transitional task in the first process and a mapping one in the second process. State assigned could be a significant state in the common vision of the life cycle of a proposal. In that case, state assigned can be considered a hidden state in the second process: it logically follows the initial state of a proposal as a consequence of task assign and precedes state “withReviews”. This hidden state can be made visible as follows. State “Proposal, assigned” is added to the process model and task assign is connected to it with a dashed arc so as to emphasize that it is a hidden state made visible. The new state has no outgoing links as it activates no tasks. The modified process along with the updated life cycles are shown in Fig. 5.

The algorithm for extracting the entity life cycles includes the new state in the outgoing paths of task assign: as a result, state assigned is the successor of the initial state, and state withReviews is the successor of state assigned. The algorithm adds final states to task notify and to the aggregator task, but these states are not shown in Fig. 5.

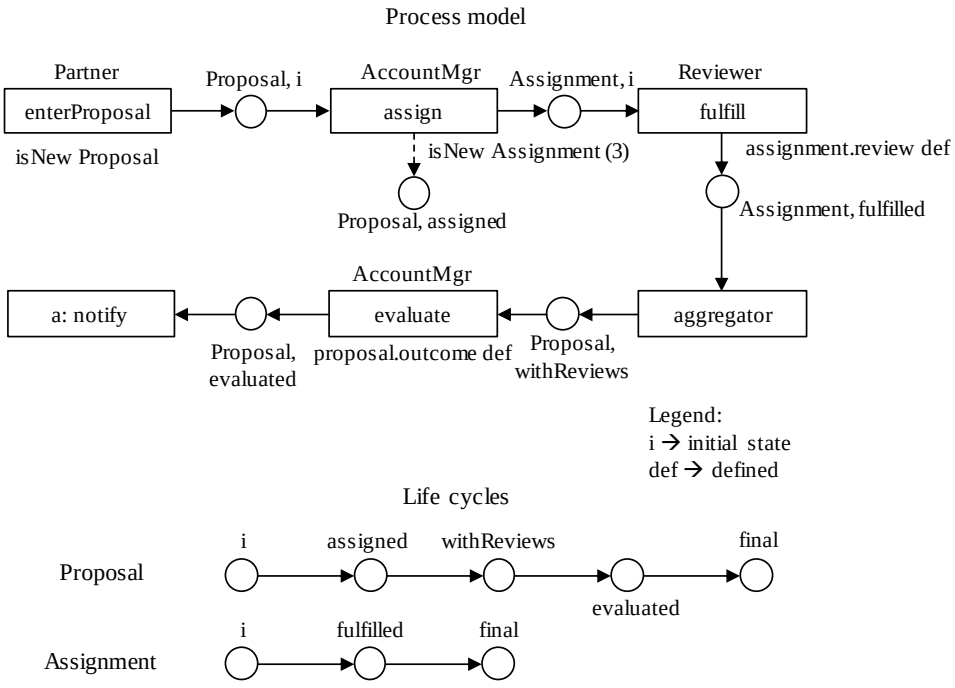


Fig. 5. The model of process CheckProposals2 with hidden states and the life cycles extracted

5. Conclusion

This paper has presented the ELBA notation which is aimed at integrating the notions of dataflow and entity life cycle. The dataflow shows the input and output entities of tasks in terms of types and states. The states of the entities of a given type are the constituents of the life cycle of that entity type.

The main difference between ELBA and GSM, which is the major representative of the artifact-oriented approach, is that process models in ELBA result from the intertwining of entity life cycles, while in GSM they are made up of separate entity life cycles. This paper has described an algorithm that is able to extract the entity life cycles from process models.

The changes of state in two or more life cycles may be interrelated: in GSM the interrelationships are orchestrated by means of ECA rules and are not shown graphically. On the other hand, ELBA considers such interrelationships as the effect of spanning tasks, i.e., tasks having inputs of different types. Such tasks can be used to synchronize input flows of different types.

Further work on ELBA is devoted to the introduction of collaborative features so as to enable processes to interact on the basis of agreed protocols. Such extensions are meant to be applied to the realm of Cyber Physical Systems.

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Biographical notes

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