Waterfall-Agile challenges in software development projects

Abstract
Software development projects remain plagued by cost and schedule overruns despite evolving methodologies. Hybrid approaches, like Waterfall-Agile, attempt to improve results by combining upfront planning with iterative development. This methodology places the customer at the center of the software development process, highlighting the critical role of relational capital, but lacks an understanding of its impact on project outcomes. This research addresses this gap by employing a simulation model to identify when and how relational capital influences project results and suggest strategies for improvement. Our findings reveal a significant effect of relational capital on project dynamics, ultimately affecting success. The study contributes theoretically by promoting system dynamics in other research fields and practically by offering managerial recommendations to enhance project results. We also highlight potential future research avenues.

Keywords: Project Management; Agile; Relational Capital; Service quality; Service erosion; Value co-creation; System dynamics

1. Introduction

Time and cost overruns remain all too common in the software industry, with specialized reports indicating that over two-thirds of software projects experience delays and budgetary overruns[1]. Project management holds immense potential for improvement, offering the prospect of significant cost savings in an industry that is predicted to surpass 1 trillion US Dollars in 2024.

Hybrid Agile project management methodologies has witnessed a surge in adoption over the past decade (Křivánková and Remta, 2023), building on Agile's adoption success. Since its introduction in 2001 in the Agile Manifesto (Beck et al., 2001), Agile's importance has been growing as a project management method for software development (Sarangee *et al.*, 2022; Patel, 2021), promising better results than its predecessors such as approaches based on the waterfall methodology (Repenning, Kieffer and Repenning, 2017; Conforto et al., 2016). However, challenges such as the potential for inadequate documentation, limited scalability, difficulty in managing large and complex projects, and the growing reluctance of clients to accept the inherent risks of Agile's flexible approach lead to the adoption of hybrid modes of Agile implementation, introducing fixed budgets and schedules into Agile projects, blending traditional plan-driven methodologies with Agile principles (Imani, Nakano and Anantatmula, 2017).

The Hybrid methodologies try to benefit from Agile's approach emphasizing an iterative, incremental, and adaptable approach, with feedback and validation throughout the project's lifecycle (Sarangee et al., 2022), while at the same time befitting from the safety of commitments regarding a scope, a project plan, and a cost from waterfall methodology. Reiff and Schlegel (2022) identified four different Hybrid Agile approaches (Water-Scrum-Fall; Waterfall-Agila; Hybrid V-model; Agile-Stage-Gate) but our focus is on the Waterfall-Agile that uses the waterfall methodology for the requirement analysis, budget and planning, and Agile Methodology for the design, development, implementation, integration and testing. This approach facilitates swift and effective

[1] Ex: Essential Software Project Failure Statistics in 2023 • ZipDo; Project Management Statistics 2023: New Trends | TeamStage

adaptation to evolving requirements and business needs, supported by the collaboration between customers and service providers.

Waterfall-Agile inherits Agile´s focus on customer involvement (Beck et al., 2001), engaging customers as active participants in the development cycle. Customers provide valuable business insights, test the software, and offer continuous feedback, validation, and guidance (Glaiel, Moulton and Madnick, 2014). This continuous interaction fosters the accumulation of relational capital, a valuable asset that marketing research defines as the network of personal relationships individuals develop with others over time (Cummings and Dennis, 2018). These relationships form an essential foundation for the success of Agile software development projects.

Agile places great emphasis in collaboration for which relational capital is critical. Relational capital's influence on the behaviors and expectations of team members (Villena, Revilla and Choi, 2011; Chan, Yim and Lam, 2010) manifests itself as a dynamic interplay of positive and negative outcomes (Villena, Revilla and Choi, 2011) that change over time (Autry and Golicic, 2010), producing experiences that feed back to reshape relational capital. Despite its central role in software development, relational capital remains an under-researched aspect of project success. The present research aims to fill this gap by conducting an in-depth investigation of relational capital development Waterfall-Agile projects, analyzing its impact on project outcomes, and exploring effective strategies for its management to improve projects' results.

Two research questions aim to improve Waterfall-Agile effectiveness in software development:

- In what way does relational capital affects the Waterfall-Agile projects' implementation?
- How can we leverage relational capital for better outcomes in terms of cost, schedule, and quality?

These require combined theoretical and empirical exploration using literature review, data analysis, and simulation modeling.

The next section presents a literature review that underpins our theoretical framework, exploring the positive and negative influences of relational capital on software development projects. We delve into the Waterfall-Agile methodology, followed by an overview of relational capital's impact on project management. Empirical evidence is then gathered from various Waterfall-Agile project implementations, providing a quantitative assessment of project progress. The system dynamics method is introduced as the basis for our simulation model, enabling us to address our research questions. The concluding sections summarize key findings, discuss theoretical and managerial implications, outline limitations, and suggest directions for future research.

2. Literature review

To address our research questions, we conducted a literature review that encompasses project management and relational capital literature. This interdisciplinary approach was essential for developing our theoretical framework and creating a robust model.

2.1. Waterfall-Agile in software development

Hybrid project management methodologies combine plan-based with flexible, customer centric methodologies trying to combine the advantages from both management systems. Reiff and Schlegel (2022) identified four different Hybrid Agile approaches:

- Water-Scrum-Fall. Combines the traditional Waterfall methodology with agile Scrum, using Waterfall in the initial (requirement analysis, planning) and final phases

(integration and testing), while Scrum (an Agile methodology) is used during the software development phase.

- Waterfall-Agile. Like the previous, combines the waterfall methodology with Agile. The difference with Water-Scrum-Fall is that Waterfall is only used in the initial phase, while both the development and testing use Agile methodology,
- Hybrid V-model. Uses the V-model (plan-based methodology) in the first phase for the requirements and planning, switching to Scrum for software development, switching back to the V-model for testing and integration.
- Agile-Stage-Gate. Very common for product development integrating throughout the entire process the Stage-Gate methodology administrative and strategic activities, and Agile for operative activities.

We focus on the Waterfall-Agile methodology because it is one of the most common and where we believe the impacts from relational capital is more significant.

The Waterfall-Agile depicted in Figure 1 starts using the waterfall approach for the definition of requirements and planning. The service provider produces schedule and cost estimations for the development of a certain software. The results are a concrete scope of the project, with negotiated commitment of resources under a pre-determined budget. This scope originates the Project Backlog which is then planned using Agile methodology taking an iterative, incremental, and adaptive perspective (GAO, 2020; Beck et al., 2001). The Project Backlog is divided into short development cycles, known as "sprints", at the sprint planning meeting, which allow teams to adapt their plans and deliver working software in manageable increments. Each sprint has its own Backlog which includes all tasks planned to be developed during the sprint duration. During the sprint, as the software is being developed and tested, a daily 15-minute meeting is held for the team to discuss issues, share progress, and identify potential hurdles. At the conclusion of the sprint, another meeting called sprint review takes place to assess the sprint's outcomes, identify lessons learned, and refine the strategy for future sprints.

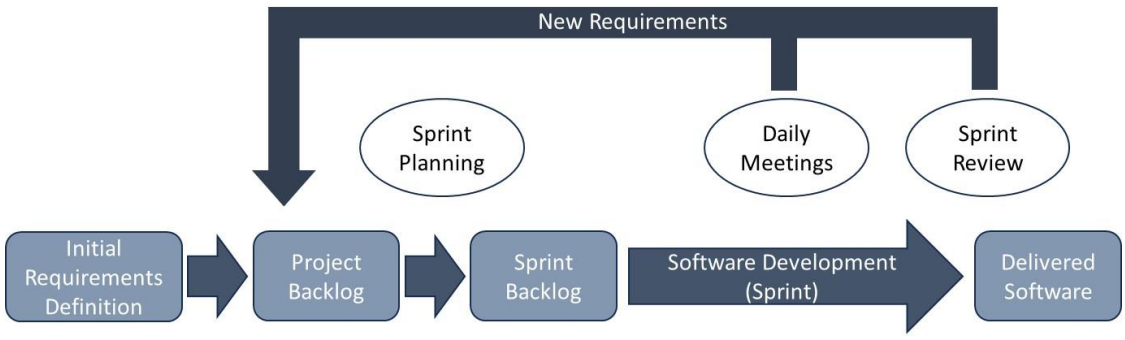

Figure 1 - Simplification of the Agile Process

The Agile inheritance embraces the continuous evolution of requirements and technology (Conforto et al., 2016) and prioritizes collaboration between the project team that includes members from the service providers and from the customer, ensuring that software requirements and user feedback are incorporated throughout the development process adding tasks to project backlog, certifying that quality, functionality, and customer satisfaction are continuously evaluated (Repenning, Kieffer and Repenning, 2017; GAO, 2020). Customers have an unprecedented role in being involved constantly and proactively (Rebentisch *et al.*, 2018), and their commitment is a requirement for the projects' success (Cao, Ramesh and Abdel-Hamid, 2010). The customers' active involvement is a key factor in the scope definition (Imani, Nakano and Anantatmula, 2017), the

continuous planning and definition of priorities, and giving feedback and validation (Rebentisch *et al.*, 2018) in daily/weekly meetings and reviews.

This intense participation from customers promotes the development of relational capital, that captures the affective nature of relationships (Cummings and Dennis, 2018), leading to the development of personal ties (Villena, Choi and Revilla, 2020), shaping the relationship between the customer and the service provider over time (Villena, Revilla and Choi, 2011). These relationships play a critical role in the success of projects following Hybrid methodologies as their success factors identified by Reiff and Schlegel (2022) have relational capital at their center, either by considering the alignment between the project team, the organizational objectives and the project implementation team, the focus on the flexibility to integrate changing business needs, or the change in company culture, norms and processes,

Altogether, it looks like relational capital impacts directly the most important problems in software development:

- Rework (Abdel-Hamid, 1984; Lyneis and Ford, 2007; Li *et al.*, 2018);
- Initial underestimations (Abdel-Hamid, 1984; Luna-Reyes *et al.*, 2008; Franck *et al.*, 2017);
- Changing Requirements and scope (Lyneis and Ford, 2007; Choi and Bae, 2009; Godlewski, Lee and Cooper, 2012);
- Changing objectives and goals (Choi and Bae, 2009)

2.2. Relational Capital

The previous section has shown that Waterfall-Agile methodology requires a deeper understanding of relational capital. Relational capital involves the strength of the relationship built over time and refers to trust, collaboration, and friendship that actors have developed with each other through a history of interactions (Villena, Revilla and Choi, 2011; Cummings and Dennis, 2018). These interactions are the stepping stone to the development of good and close relationships (Aisyah, Sukoco and Anshori, 2019) that can influence the behaviors and expectations of the team members (Villena, Revilla and Choi, 2011; Chan, Yim and Lam, 2010). These close relationships are known to generate positive experiences but can also generate negative experiences when they evolve into “cozy relationships” referring to close, often too familiar, and potentially inappropriate relationships between two or more individuals or entities (Villena, Choi and Revilla, 2020; Anderson and Jap, 2005).

The positive effects of fostering relational capital, shown in Figure 2, refer to the belief in its positive impact on project results. While the project is being developed (Project Work Done) experiences accumulate enabling the development of Relational Capital (Villena, Revilla and Choi, 2011). The development of relational capital improves communication (Gligor and Holcomb, 2013) and business knowledge (Noordhoff *et al.*, 2011; Martins, Duarte and Costa, 2018; Lee and Ha, 2018), ultimately improving productivity (Aisyah, Sukoco and Anshori, 2019; Zardini, Ricciardi and Rossignoli, 2015; Bagdoniene and Valkauskiene, 2018). By increasing productivity additional project work is done that will further increase the relational capital (Lee and Ha, 2018; Zardini, Ricciardi and Rossignoli, 2015; Villena, Choi and Revilla, 2020).

Note to interpret the figures: the plus sign (+) means that the variables change in the same direction, while the minus sign (-) means that they change in the opposite direction.

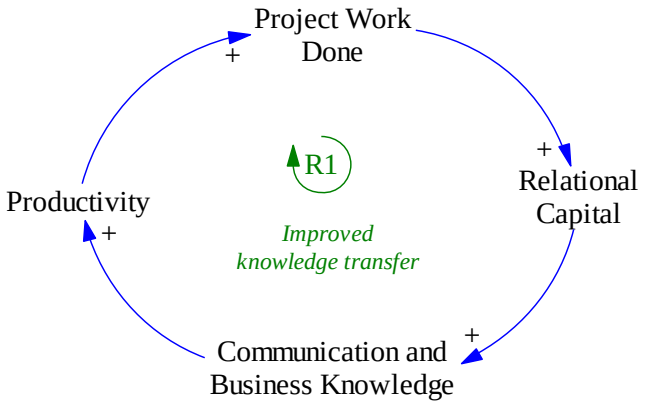

Figure 2 – Positive Effects from Relational Capital in Agile Projects

Regarding the negative effects, Figure 3 depicts the appearance of cozy relationships as the result of the development of relational capital (Rood *et al.*, 2018; Autry and Golicic, 2010). Cozy relationships will decrease the willingness to monitor activities (Villena, Choi and Revilla, 2019) eventually leading to an increase in errors and consequent productivity decline.

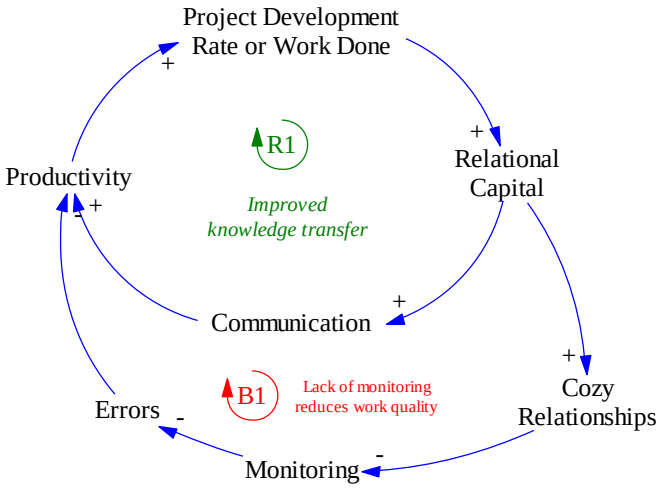

Figure 3 – Negative effect from neglecting monitoring

Additionally, Figure 4 depicts that cozy relationships can generate an erosion of standards (Villena, Choi and Revilla, 2020), understood as the normal levels of service provision, eventually leading to an increase of errors and declining productivity. Moreover, cozy relationships contribute to blurring lines between the service provider and the customer (Pillai *et al.*, 2017), hindering the capacity to define adequate goals, which are the levels of a certain variable that the project team aims to achieve. Altogether, these effects erode performance, ultimately decreasing the relational capital that accumulates over time (Villena, Revilla and Choi, 2011).

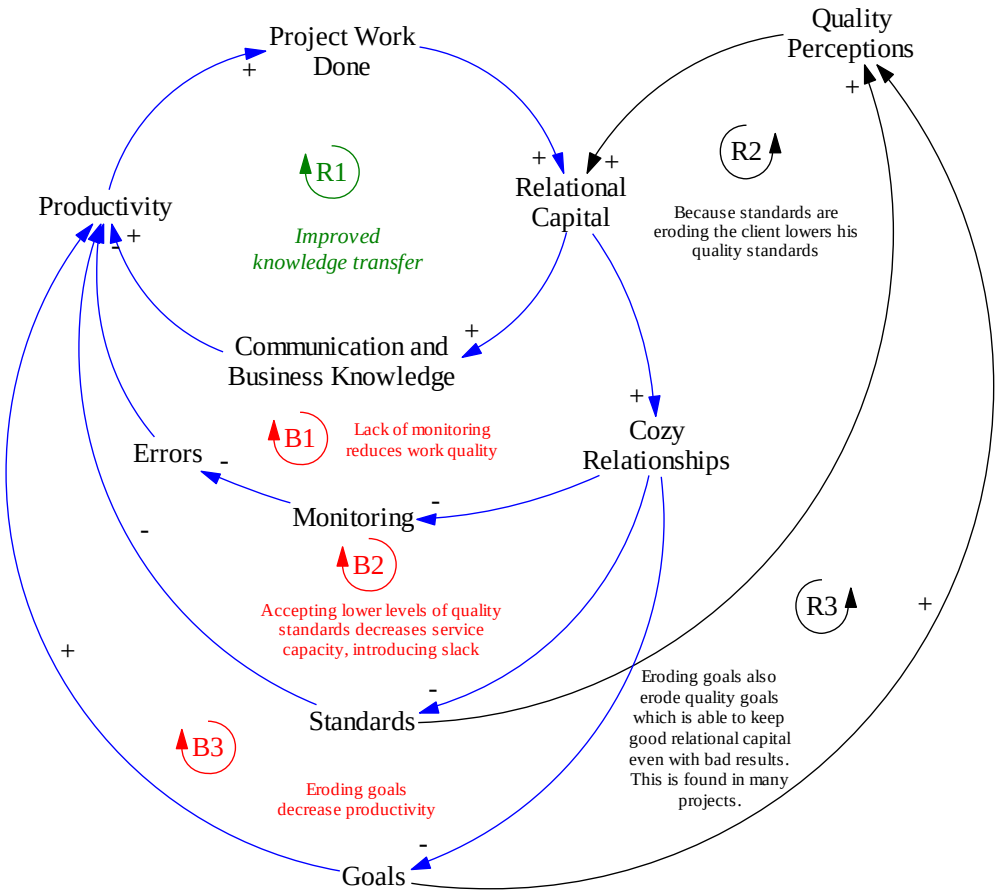

Figure 4 - Theoretical framework. Combination of Positive and negative effects of relational capital

The preceding literature review provided the theoretical framework for answering our first research question: In what way does relational capital affects the Waterfall-Agile projects' implementation? This is done by introducing a novel approach to tracking relational capital's accumulation, and combined positive and negative effects over time, which includes the adjustment to lower quality perceptions. To answer our second research question (How can we leverage relational capital for better outcomes?), we need more information on the strength and timing of the six interacting loops. For that we need 1. a method to analyze a complex issue over time and 2. empirical measurements. Therefore, we employed a system dynamics simulation model to deal with complexity, and we collected real project data to get the necessary reference modes.

3. Methodology

The study employed a multi-method approach to test the theoretical framework. Project data from various project sizes enhanced the model's real-world applicability. Finally, building upon the theoretical framework, qualitative data, decision rules, and project data, a system dynamics simulation model was developed, allowing us to simulate project scenarios, evaluate management strategies, and identify performance improvement strategies.

3.1. Case Study

Process

To answer the research questions through an inductive lens, we partnered with Company A, a renowned Portuguese software development company with diverse clients across various industries. We collected quantitative data from real projects conducted by Company A. Access to their project

management system provided a comprehensive overview of project features, including hours worked, subcontracts, expenses, and other relevant details. This multi-project approach enabled a deeper understanding (Miles and Huberman, 1994) of software development processes Our selection criteria ensured a representative sample, with projects adhering to Waterfall-Agile methodologies and executed after 2020. The sample included four projects following Waterfall-Agile, all within the financial industry, and provided valuable insights into the company's software development processes.

Data were collected between August and October 2023 and were organized into an Excel file for time-based analysis. A member of the company's planning and controlling department assisted in data collection, and discussions with the Director for Planning and Controlling enhanced data understanding. Data analysis began by creating tables comparing initial project plans to actual execution, identifying discrepancies, and determining their causes and resulting decisions.

Results

Analyzing initial project plans and assumptions revealed experienced staff planned allocation at 55% and team stability expectations. Figures 5-8 and Table 3 summarize project plans and results. These include planned and actual data on hours, staff, and experience level for each project.

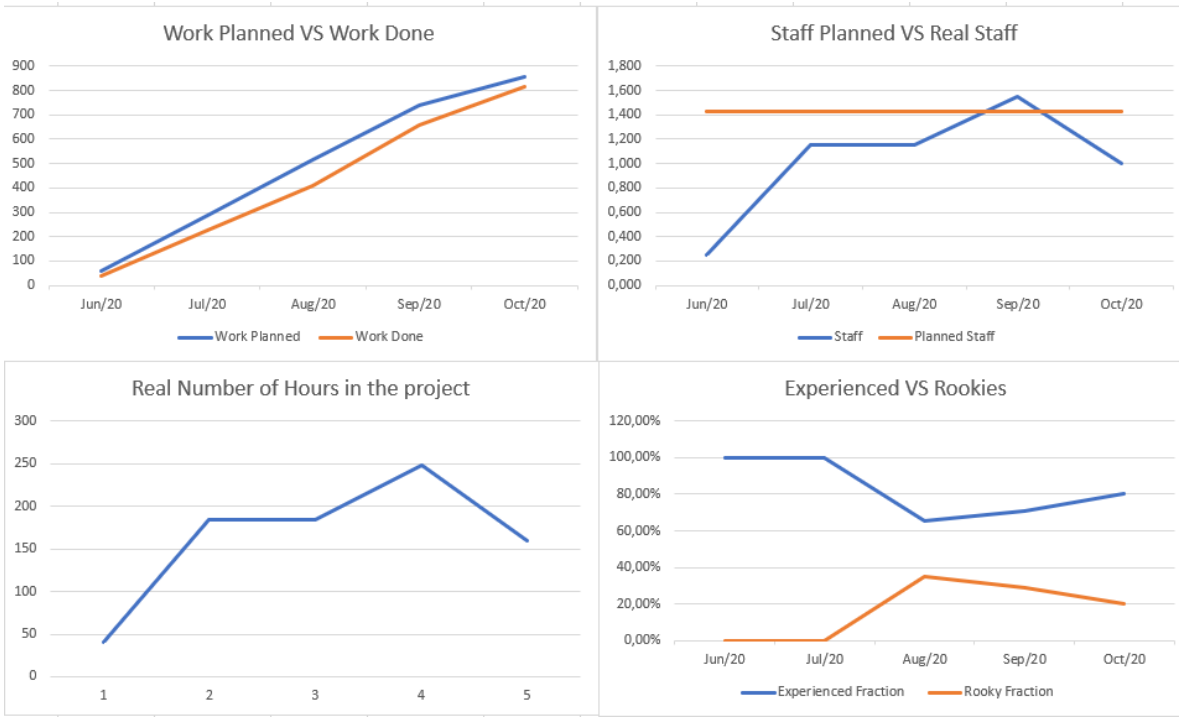

Figure 5 - Project 1 data summary

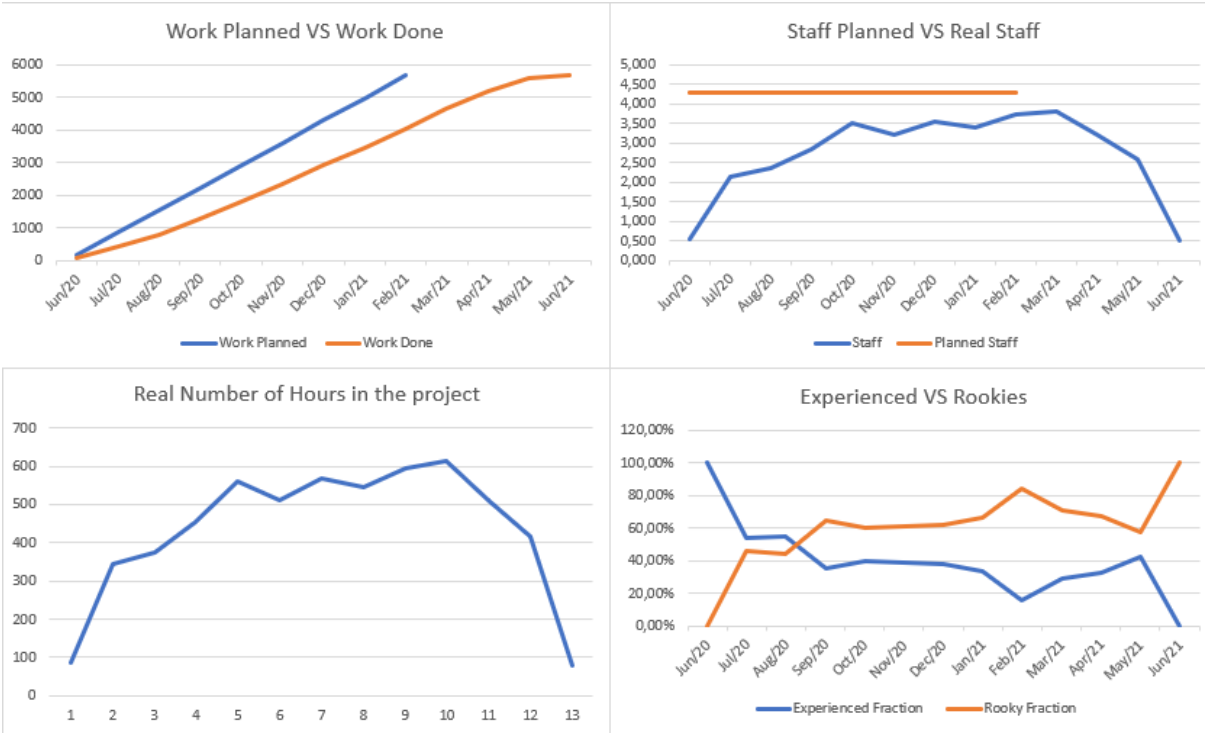

Figure 6 - Project 2 data summary

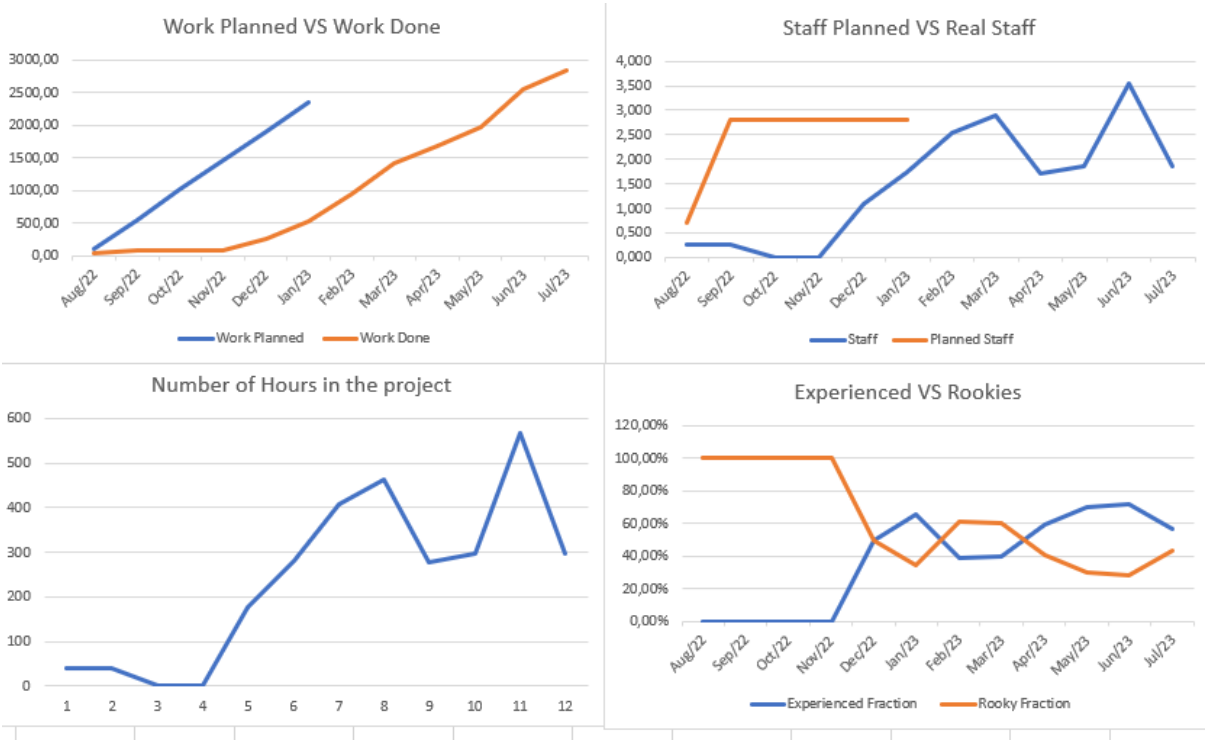

Figure 7 - Project 3 data summary

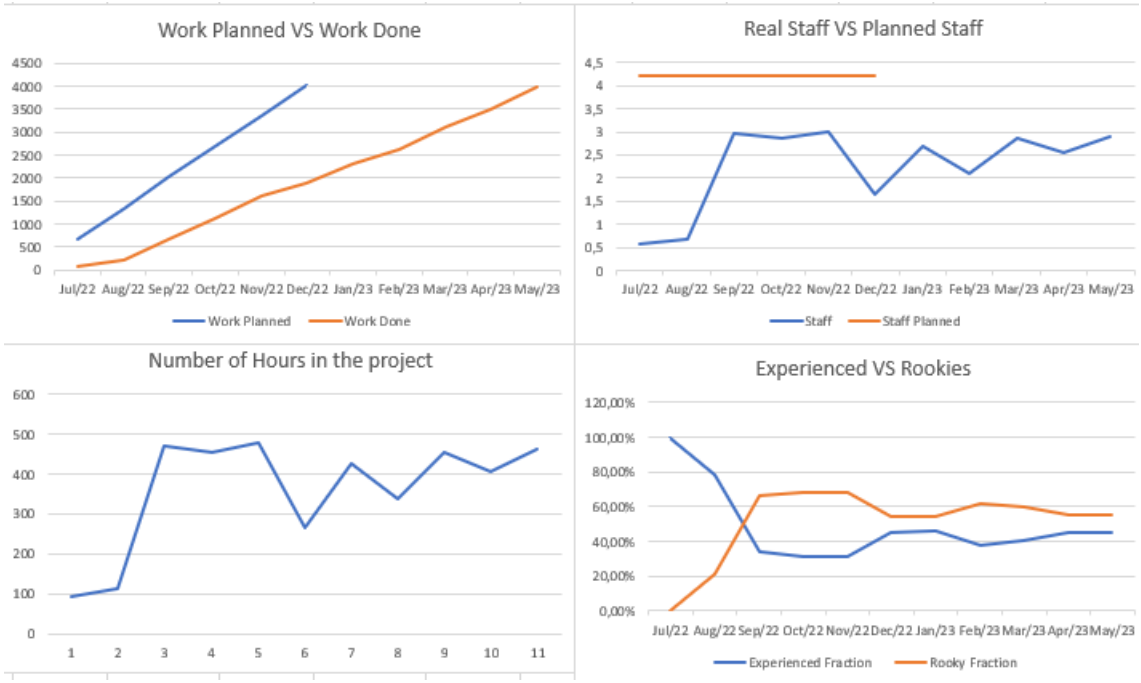

Figure 8 - Project 4 data summary

Table 1 - Summary of Plan VS Real Project Indicators

Project	Type	Cost			
		Plan	Real	Diference	%
1	Hybrid	€ 23.778,88	€ 25.536,72	€ 1.757,84	7,39%
2	Hybrid	€ 136.353,45	€ 141.726,35	€ 5.372,90	3,94%
3	Hybrid	€ 56.212,98	€ 62.741,33	€ 6.528,35	11,61%
4	Hybrid	€ 109.782,00	€ 159.560,00	€ 49.778,00	45,34%
	Average for cost	**€ 81.531,83**	**€ 97.391,10**	**€ 15.859,27**	**17,07%**
Project		**Schedule (weeks)**			
		Plan	Real	Diference	%
1	Hybrid	15	17	2	13,33%
2	Hybrid	33	48	15	45,45%
3	Hybrid	21	40	19	90,48%
4	Hybrid	24	44	20	83,33%
	Average for schedule	**23**	**37**	**14**	**58,15%**
Project		**Staff**			
		Plan	Real	Diference	%
1	Hybrid	1,43	1,02	-0,41	-28,50%
2	Hybrid	4,29	2,72	-1,57	-36,54%
3	Hybrid	2,81	1,48	-1,33	-47,23%
4	Hybrid	4,20	2,25	-1,95	-46,32%
	Average for staff	**3,18**	**1,87**	**-1,31**	**-39,65%**
Project		**Experience Level**			
		Plan	Real	Diference	%
1	Hybrid	80,37%	79,41%	-0,01	-1,20%
2	Hybrid	36,73%	36,73%	0,00	0,00%
3	Hybrid	68,49%	54,99%	-0,13	-19,71%
4	Hybrid	36,90%	41,73%	0,05	13,09%
	Average for experience	**55,63%**	**53,22%**	**-0,02**	**-1,95%**

First important lesson from the data is that projects were understaffed overall, with 39,65% fewer people than originally planned. Figures 5 – 8 show significant changes in team allocation, and adequacy of staffing were also observed.

Another important lesson is that all projects included in this study have overruns. They experienced schedule overruns of on average 58.15%, while cost overruns remained lower at 17%. While time overruns are straightforward to identify, analyzing cost overruns requires caution due to the challenges in tracking overtime accurately and the pressure project managers face to adhere to initial cost estimations, potentially leading to cost dilution across other projects.

Finally, going beyond data on single projects and looking at follow-up projects for the same client, an interesting dynamic was observed reinforcing our theoretical framework. Despite project overruns, clients continue to sign new contracts with Company A, often choosing the same team for new projects. Both parties appear to accept overruns as the norm, potentially raising concerns about declining project goals or standards.

3.2. System Dynamics

System Dynamics emerged as the ideal choice for our research due to its proven track record and ability to handle complex problems involving feedback loops, nonlinearities, delays, and accumulation over time (Sterman, 2000; Gao and Zhang, 2022). System Dynamics has been extensively employed in software development project management since the late seventies. In the context of Agile projects, System Dynamics has been applied to study overall project dynamics (Cao, Ramesh and Abdel-Hamid, 2010; Glaiel, Moulton and Madnick, 2014; Van Oorschot, Sengupta and van Wassenhove, 2009), the transition from traditional to Agile methods (Sarangee *et al.*, 2022; Cocco *et al.*, 2011), and the potential of hybrid approaches (Imani, Nakano and Anantatmula, 2017). Additional studies have examined team dynamics and productivity (Ching and Mutuc, 2018; Fatema and Sakib, 2018), iteration length effects (van Oorschot, Sengupta and Van Wassenhove, 2018), product development (Rebentisch *et al.*, 2018), and project performance (F. Tripp and Armstrong, 2018).

Our research delves into the significance of relational capital in Waterfall-Agile project management, adopting a rigorous approach that builds a theory through a logical sequence of steps, testing and refining it iteratively with data (Homer, 1996; Schwaninger and Grösser, 2008). The model we developed expands upon existing models of Agile projects (Cao, Ramesh and Abdel-Hamid, 2010; Glaiel, Moulton and Madnick, 2014), adding a Hybrid approach (Imani, Nakano and Anantatmula, 2017), and incorporating structures previously developed by the authors that capture the impact of relational capital accumulation. The next section presents a detailed description of the model, its validation and parameter estimation strategy, which allowed for testing its robustness and reliability.

4. Model structure

Building upon the theoretical model in Figure 4, our system dynamics simulation model incorporates five sectors (Figure 9), leveraging structures from previously published system dynamics studies whenever possible. The **software development sector** tracks work completion and defect generation/discovery. The **quality sector** reflects the impact of management decisions on quality and error probability. These interact with project development rate and quality through service capacity and planning and control. The **service capacity sector** considers the team's ability to deliver tasks, accounting for experience, productivity, and time allocation. The **plan and control sector** reflects ongoing work oversight and management responses to deviations from goals. Finally, the **relational capital sector**, novel to project management system dynamics models, explains how relational capital development impacts all previous sectors over time. It also incorporates policies for managing relational capital to enhance project outcomes.

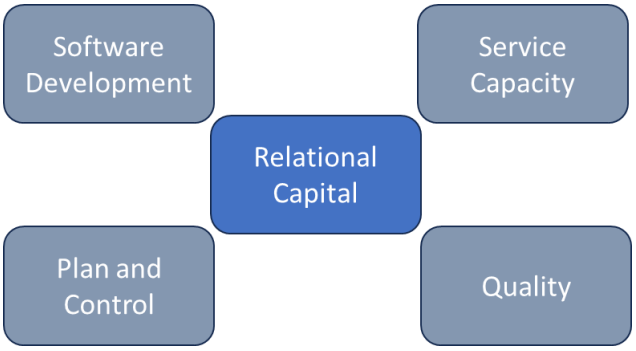

Figure 9 - Sector model

We now expand the software development sector to provide a comprehensive understanding of the Waterfall-Agile process of software development. Subsequently, we shift our focus to the relational capital sector to introduce a novel structure that enables the management of relational capital to enhance project outcomes. (Due to space limitations, we provide a brief overview of the remaining structures, as they are grounded in previous research.)

4.1. Waterfall-Agile software development sector

The software development sector draws on established research on the agile software development process using system dynamics methodology (Cao, Ramesh and Abdel-Hamid, 2010; Becker, 2017; Glaiel, Moulton and Madnick, 2014; Rebentisch et al., 2018). Figure 10 illustrates the process, where stock variables, such as Project Backlog, represent accumulations of work, and flows, like release planning and sprint planning, depict the rates of transfer from one stock to another. The project starts with an initial project backlog that encompasses all planned work for the project, quantified in development hours, mirroring the reality of the projects under investigation. This project backlog is subsequently divided into distinct sprints, represented by the Sprint Backlog. We have chosen not to incorporate a Release Backlog due to its absence in the project development practices of “Company A”. Software production occurs within the "sprint" segment of the model and is influenced by factors such as service capacity and the probability of error generation.

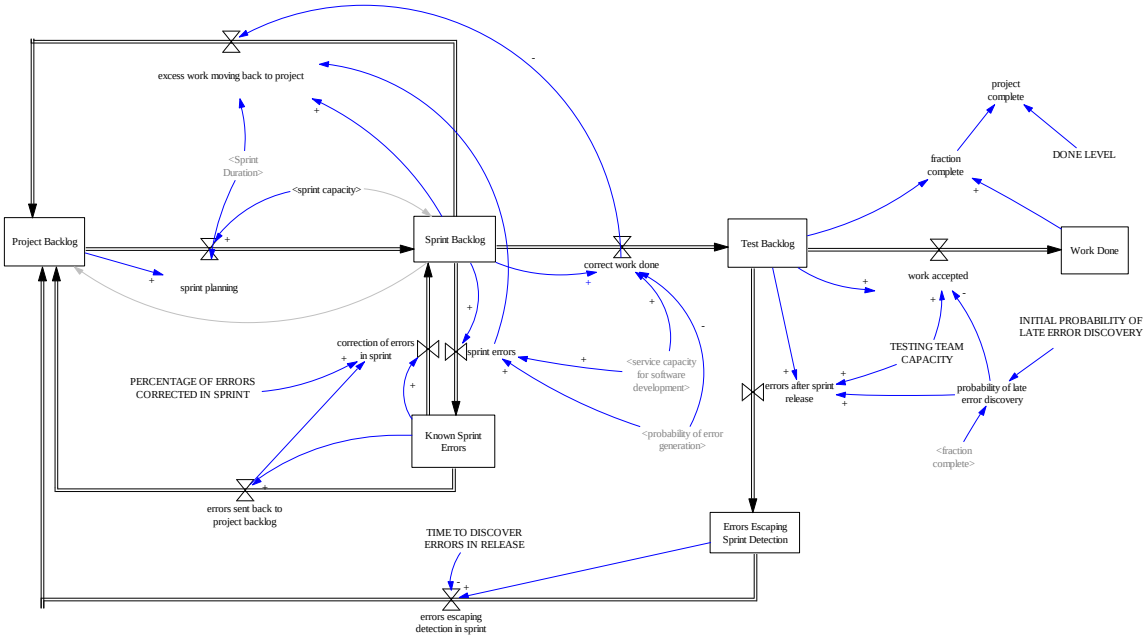

Figure 10 – Waterfall-Agile Software development structure

As work progresses, a portion deemed correct and complete accumulates, awaiting further testing. However, some tasks contain errors that either are corrected within the same sprint or transferred back to the Project Backlog for replanning. The sprint ends when either the sprint backlog reaches zero or the sprint duration time expires. In the latter case, the incomplete work is shifted back to the Project Backlog for rescheduling.

4.2. Relational capital sector

The relational capital structure depicted in Figure 11 uniquely captures the causes and consequences of changes in relational capital. Unlike previous models, which focused solely on customer participation, our model (Figure 11) considers the full effects of "relational capital" on project outcomes. This builds on research showing customer participation's impact on trust (CAO

2010), and requirement management (GLAIEL 2014). We introduce relational capital theory, accounting for both its positive and negative influences. The model uses a scale (1-5, where 1 is the lowest value and 5 is the highest value achievable) to evaluate the relational capital from Barão and Silva (2011), which we normalize to focus on changes rather than absolute values. This allows for broader application and use of empirical data.

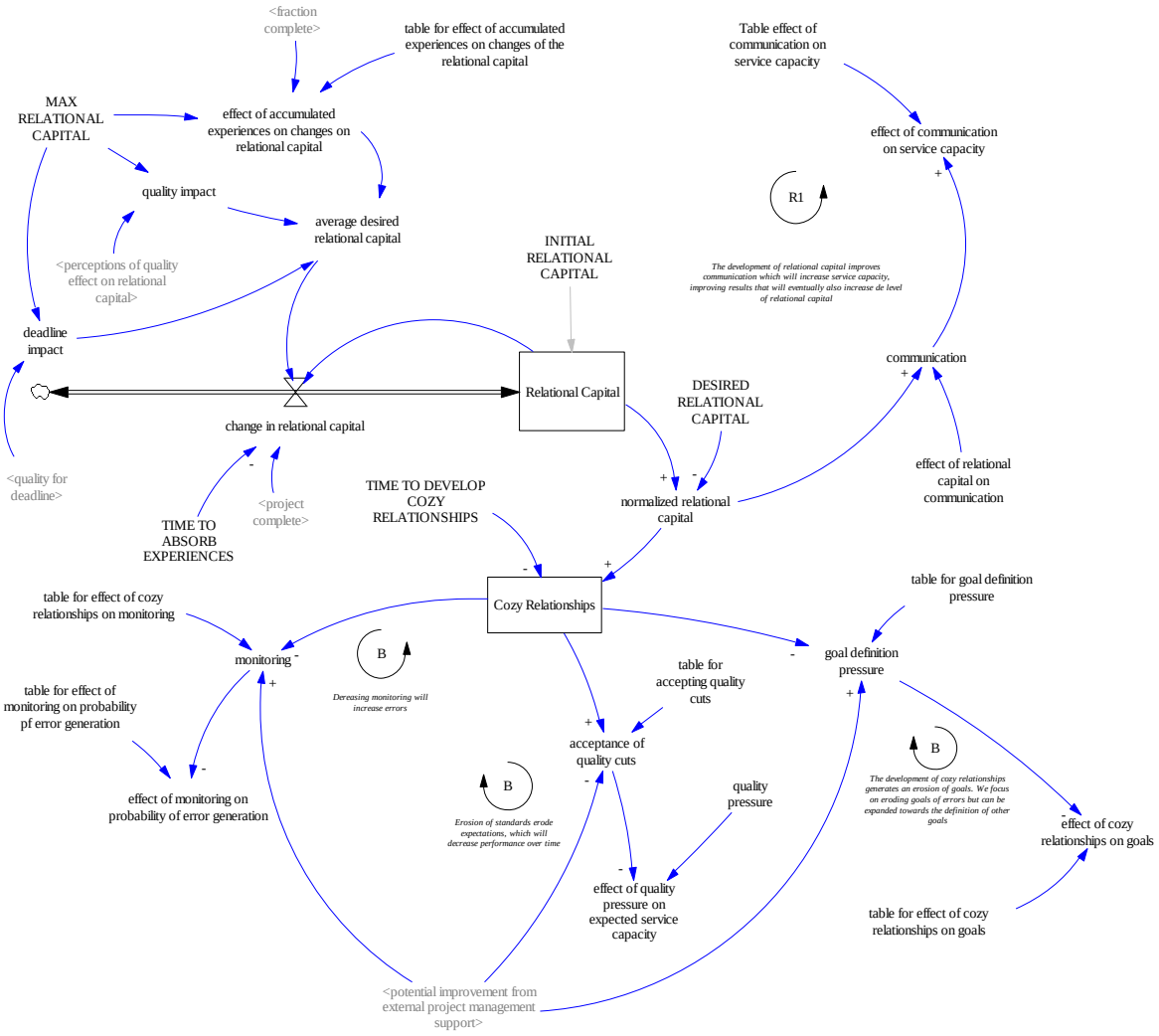

Figure 11 - Relational capital structure

As projects progress, relational capital develops through interactions and experience, enhancing communication and knowledge sharing, thereby boosting service capacity through a nonlinear function employed as a multiplier. However, relational capital brings with it the risk of creating cozy relationships, leading to reduced monitoring, lower standards, and goals, and impacting quality perceptions, ultimately affecting performance. The model continuously adjusts the relational capital value based on performance indicators, ensuring responsiveness to changing dynamics.

4.3. Other sectors

The service capacity sector adapts the framework from Oliva and Sterman (2010), distinguishing between rookies and experienced staff. Productivity is expressed as experienced equivalent, and experienced employees' time allocation is diminished by their involvement in training rookies and providing commercial support. Moreover, service capacity considers the time invested in the

mandatory Agile meetings because they are integral to the Agile development process. We include a separate service capacity for final approval of sprint tasks to allow scenarios with independent resources, such as the customer investing in testing or subcontracting third parties, which is a common practice in software development projects.

The plan and control sector comprises two sub-sectors: schedule management and capacity adjustment. To manage deadlines and schedules, we focus on the project schedule to accommodate the hybrid approach. This structure draws inspiration from prior project management models (Ford, Lyneis and Taylor, 2007; Jalili and Ford, 2016; Li et al., 2018), where the scheduled time remaining is calculated based on the project deadline and the project's development time, yielding a desired software development service capacity to complete the work on time. With the desired service capacity we capture the management decisions to adjust capacity inspired by Li et al. (2018), where we incorporate the traditional project management responses of altering work intensity, overtime, and workforce to adapt to changing project needs.

The quality sector also has two sub-sectors. The first one covers the probability of generating errors, which depends on the levels of fatigue, inexperience, work intensity, and monitoring, and is inspired by Lyneis and Ford (2007) and Oliva and Sterman (2010). The second one introduces the service quality from Parasuraman and colleagues (1985), who define service quality as a gap between expectations and perceptions from the client. The present research uses the Oliva and Sterman (2010) approach to the concept but applies it to service capacity, probability of error generation, work done, and schedule overruns.

4.4. Model Validation

The model was tested using Sterman's (2000) approach and it was confronted with real data from the sample of projects described earlier in a Portuguese software development company. The model's behavior for typical conditions is consistent with previous project management models and the reference modes from the projects analyzed. The use of structures developed and tested in previous published system dynamics work improves confidence in the structure and behavior of the model presented. The model units are consistent with units used in real projects, and there are no ambiguous conversion variables.

5. Results

Analyzing Company A's projects, combining project data and exploring simulations revealed key issues:

1. Even though projects overrun, relational capital still grows, giving cover to a pervasive erosion of standards and goals, locking both the service provider and the customer in sub-optimal performances.
2. Understaffing is common, leading to pressuring staff or extending timelines. This might be linked to Company A's growth policy and reluctance to exceed capacity. Understaffing can also result from the underestimation of the required "experienced equivalent" in the initial planning, and from failing to consider that errors cause rework, which requires additional capacity to correct.
3. Underestimation of project effort is prevalent, partly due to the inherited Agile practice of not requiring detailed initial analysis, and customers often requesting new features without complete information, hindering proper planning.
4. Staff experience mix impacts results. Starting slightly overstaffed with experienced staff (50%, as per Company A's definition) reduces schedule overruns to 16-20% compared to the observed 41% in understaffed projects.

To explore potential solutions and policies, we applied the simulation model to Company A's fictional project with the following basic assumptions: 9.600 hours of work to be developed in 60 weeks, which results in a team of 4 experienced equivalent people, working 40 hours per week. The first important reflection from these simple planning assumptions is that the number of people is measured in experienced equivalent, which means that the project requires more staff than the four individuals. The failure to plan to use an "experienced equivalent" measurement might be one of the causes why understaffing is so common in software development projects.

Our base case (Business as Usual (BAU)), depicted in Figures 12 and 13 replicates Company A's approach: active sprint capacity planning with a fixed team. We added performance measurements to compare planned vs. actual results. This base case reflects the project behavior observed in the projects analyzed. The simulation results show that even with a highly experienced team and good control over service capacity adjustments, schedule and cost overruns of around 20% are expected. This reflects the behavior observed in the studied Waterfall-Agile projects, although their cost overruns were lower. This discrepancy might be due to the pressure on results, where staff might record hours in other projects when facing overruns.

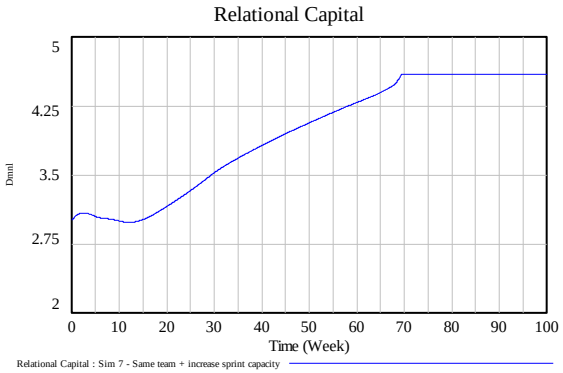

Figure 12 - Relational capital development for policy1

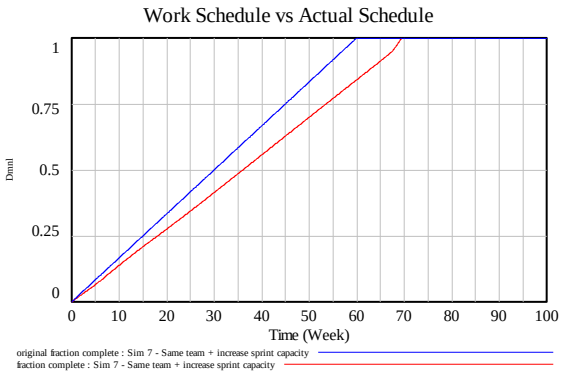

Figure 13 - Work schedule vs actual schedule for policy 1

We simulated hiring additional staff ("Change Staff") as a second policy to mimic project management decisions, depicted in figures 14 and 15. This involved hiring rookies (50%) and increasing sprint capacity alongside increasing service capacity. The project finished on time with high relational capital due to the lack of schedule overruns. However, even with further increases in staff and capacity, overruns persisted, leading to higher costs (excluding overtime and work intensity). While on schedule and with high relational capital, this approach is challenging in growth

scenarios due to limited staffing arising from policies of operating near full capacity. Here, relational capital might play a crucial role by motivating the client to invest resources and build service capacity, mitigating the need for excessive hiring and cost increases.

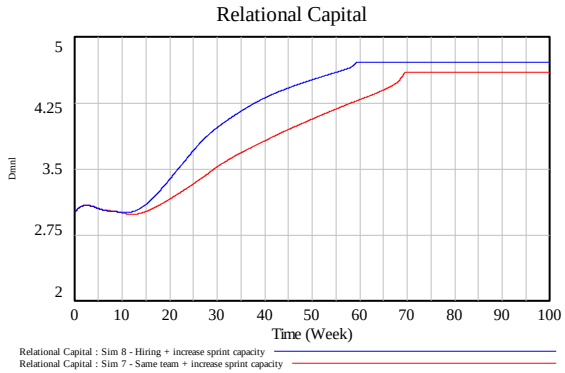

Figure 14 - Comparison between policies 1 and 2 for relational capital

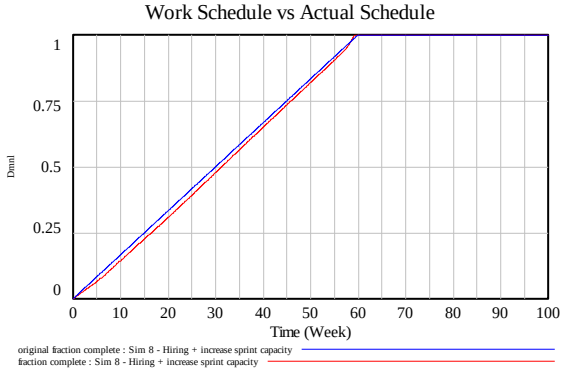

Figure 15 - Work schedule vs actual schedule for policy 2

Simulating 80% of rookie hiring ("80% Rookies") revealed the critical role of experience mix. Overruns increased to 8.3% schedule and 6.5% cost compared to 50% rookies. This scenario involved significantly more overtime, potentially leading to higher error rates. Relational capital plummeted and remained low, likely due to eroded expectations and declining quality. This highlights the risk of relying heavily on rookies, a prevalent practice outside of Company A's financial market sector.

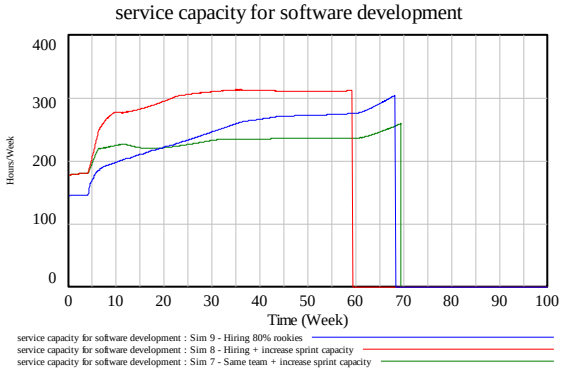

Figure 16 - Development of service capacity using policies 1, 2, and 3

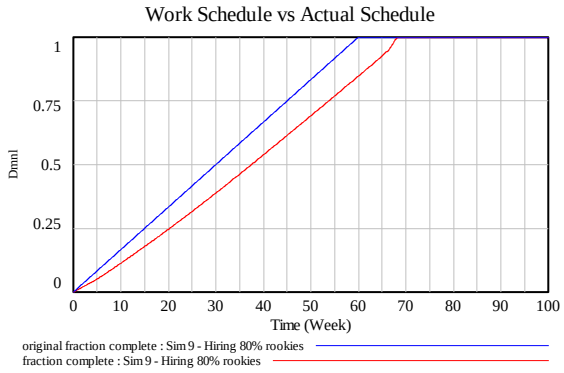

Figure 17 - Work schedule vs actual schedule of policy 3

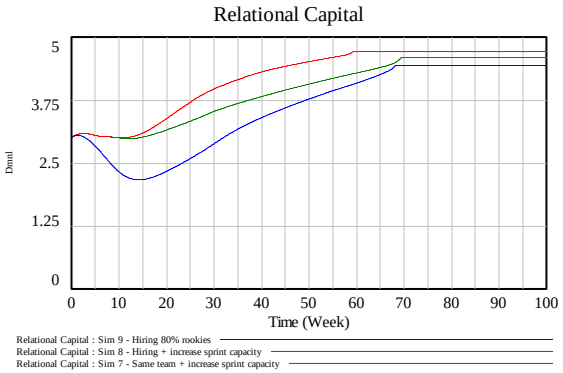

Figure 18 - Relational capital development according policies 1, 2, and 3

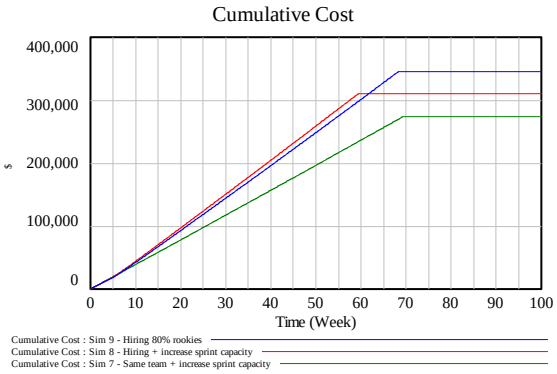

Figure 19 - Development of total cost from policies 1, 2, and 3

We tested a policy targeting desired relational capital ("Sim 10"). This approach, common in system dynamics, sets the desired level as a control variable. Here, we explore the importance of policies aiming to improve companies' relational capital. This approach provides clear direction while avoiding "cozy relationships" and emphasizing managed beneficial customer relationships. The simulation showed significant schedule overruns but the second-lowest cost overrun. This suggests insufficient relational capital growth weakens the positive effect of communication on service capacity. However, the potential for this policy is significant if measures are taken to control relational capital levels and limit its negative effects while maintaining the benefits of improved communication.

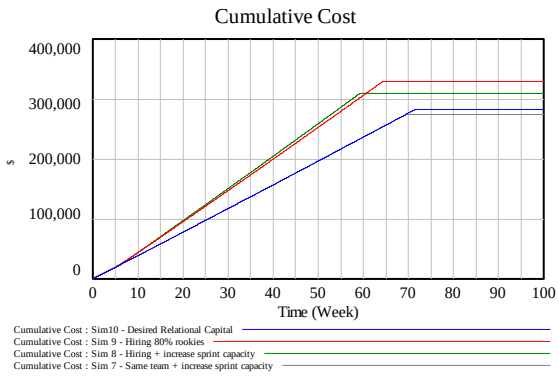

Figure 20 - Total cost of the different policies

Finally, we tested using external teams to support project management ("Ext PM Support"). We implemented an external team, including the costs for that team, but this can be implemented through matrix structures (separate development and quality teams), regular quality audits, or external project management support. This policy proved most effective, achieving near on-time completion with a 13% cost overrun. It also led to a steady increase in relational capital while minimizing negative effects.

6. Discussion and conclusion

Despite advancements in project management methodologies, many software development projects still experience cost overruns. Agile and its Hybrid variations have gained popularity due to their co-creative, iterative, and incremental approach, which emphasizes client involvement throughout the software development process. As discussed in the literature review, client involvement is crucial, providing unique business and organizational knowledge through continuous daily interactions and validation. These interactions foster relational capital, which positive and negative effects on relationship strength over time. Despite relational capital's central role in software development, little research focuses on how to effectively manage and capitalize on it in both project management and system dynamics literature.

Recognizing this research gap, we embarked on an exploration of the significance of client involvement in Waterfall-Agile methodology. This led to our first research question, which aimed to uncover how and when relational capital changes the results of Waterfall-Agile software development projects. To address this question, we delved into the literature to identify causal relationships between relational capital and its impacts. We then gathered and analyzed quantitative data from real-world projects. By employing system dynamics, we integrated these findings into a simulation model that provides clear explanations of how and when relational capital shapes the outcomes of Agile projects. Our results align with literature descriptions (e.g., Autry and Golicic, (2010, p. 87)), highlighting the short-term benefits of enhanced relational capital, including improved communication and business knowledge transfer. However, we also found that long-term negative consequences arise from the development of cozy relationships, which take time to form, and for the first time we were able to explain how relational capital remains high or keeps increasing as described by project managers, while project results keep eroding, locking organizations in sub-optimal performances.

Further model exploration allowed us to answer the second research question: what can be done to use relational capital as leverage to improve the results of Waterfall-Agile software

development projects? Similarly to what Oliva and Sterman (2010) found in a service setting, our study shows that results tend to erode if management fails to act. Our results complement the traditional project responses using schedules, work intensity, overtime, and staff and enabled us to extract some strategic lessons:

- Operating near full capacity may hinder the organization's ability to grow. If an organization is working with all productive resources allocated to projects, every time the organization wins a new project it will need to relocate staff from one project to another, which takes time and can result in two projects understaffed.
- Experienced staff are crucial for software development projects. Their higher productivity and lower error rates compared to rookies necessitate a well-balanced staffing approach. Understaffing projects, often due to overlooking this vital aspect, will negatively impact results through staff allocation and mentoring, project prioritization, and profit, among others.
- Setting clear benchmark goals for service capacity, errors, and deadlines is crucial to prevent project decline. Our model highlights the importance of using realistic benchmarks to maintain high standards and avoid their erosion.
- Monitoring systems need to evolve. Hybrid project management requires adaptable monitoring systems. Integrating continuous comparisons between planned and actual values for service capacity, errors, and schedule offers several benefits:
    - Early intervention: Allows for timely corrections, preventing problematic delays.
    - Expectation management: Aligns stakeholder expectations with project reality.
    - Improved awareness: Provides a clearer picture of the project's true state.
- Enhanced monitoring systems should be complemented by policies that prevent "cozy relationships", fostering objectivity and higher levels of control and segregation. These policies can include:
    - External quality audits: Independent assessments of project quality.
    - External project management support: Utilizing outside expertise for project planning and control.
    - Matrix organizations: Establishing dedicated teams for development and quality assurance.
- Soft variables like relational capital offer significant potential for project improvement. While it fosters communication and knowledge transfer, unchecked relational capital can lead to detrimental "cozy relationships." Implementing policies like process standardization can ensure productivity gains even with moderate relational capital growth, mitigating the risks associated with "cozy relationships." Using positive relational capital to negotiate new project deadlines can benefit the project by lowering the pressure that leads to errors and consequently more pressure. However, this must be complemented with benchmarks to avoid its overuse and sliding into the spiral of eroding goals.

6.1. Theoretical implications

Our research has challenging theoretical implications. First, it contributes to the literature on project management by enhancing our understanding of how relational capital develops and accumulates. This establishes a new bridge between marketing and project management literature. Second, it introduces the role of relational capital to the system dynamics literature applied to project management. Third, it introduces system dynamics as an excellent method to study the integration of diverse knowledge (Zimmermann and Curran, 2023), in our case project management, and marketing. We are broadening the scope of system dynamics project management models, expanding, and exposing the field to the growing importance of soft factors and behavioral decision-

making. Following the previous, our study also complements other uses of system dynamics for theory building (Hanneman, 1988; Schwaninger and Grösser, 2008). Fifth, it introduces project management as a new service setting for marketing research, where the new knowledge generated is critical to improve results as it was demonstrated by the present research. Finally, we hope to motivate service researchers to broaden their research by taking a long-term approach using system dynamics to articulate their theories as proposed in 2008 by Spohrer and Maglio (2008).

6.2. Managerial implications

Our collaboration with project managers yielded six key findings. First, by understanding the model's interconnected relationships, managers identify unforeseen consequences of their decisions, such as reduced monitoring, declining standards, and goal adjustments based on poor performance. Second, developing practical guidelines, from the knowledge gained from the model's interconnected relationships. Examples like staffing, Maintaining at least a 50% ratio of experienced employees, monitoring, comparing project progress against plans, allowing for revisions, and mitigating negative effects of relational capital through implementing clear contractual terms and establishing realistic performance benchmarks to prevent declining performance and standardizing processes and develop tools to convert tacit knowledge into explicit knowledge, promoting productivity independent of relational capital growth.

A third managerial implication is the paramount role of relational capital on expectation adjustment and goal setting. The findings show that relational capital can lead to a downward adjustment of expectations, potentially accepting lower delivery standards. To counteract this tendency, managers should establish additional benchmark goals for errors, quality, and expectations. Another key managerial takeaway is the need to reevaluate team composition. The findings suggest that a higher proportion of experienced employees can significantly improve project performance in terms of cost and time.

Fifth, we propose expanding the project monitoring system with key performance indicators (KPIs) aligned with our model findings. These KPIs, centered on managing relational capital effectively, can significantly enhance project control and prompt timely interventions. We advise managers to consider the introduction of formal service quality measurements involving clients using the scales already developed for that such as SERVQUAL and SERVPREV. Our proposed KPIs include:

- Error tracking:
  - Monitor error count throughout sprints and later testing phases.
  - Compare actual errors to expected error rates.
- Service capacity management:
  - Track "relative agile productivity" (effective agile productivity per team member).
  - Calculate and monitor "expected weekly service capacity" based on average individual productivity and team size.
  - Monitor the gap between expected and actual service capacity to identify deviations and potential delays.

Finally, our findings have the potential to be applied to projects beyond Agile methodologies due to the fundamental similarity in relational capital development and project control mechanisms across various approaches. Additionally, our insights can be extended to other business settings like consulting, construction, and service industries, which share characteristics such as knowledge intensity, intangibility, customer dependency, and frequent interactions between service providers and clients. Overall, the generalizability of our results has the potential to enhance project outcomes across a wide range of endeavors.

6.3. Limitations, future research, and concluding remarks.

This study is constrained by the availability and limitations of real-world project data. The existing data does not fully capture the scope of our research interests. Traditional corporate systems often focus on accounting aspects, overlooking crucial operational details like overtime or workload intensity. Moreover, the systems used to manage Agile backlogs were under customer control, making access challenging for researchers. Lastly, the pressure to keep project costs under control might lead to staff misreporting their labor hours, potentially affecting the data's accuracy.

Two key limitations arose during data collection. First, using project managers from various projects, not just those we collected quantitative data from, limited our ability to compare individual project managers' opinions with the corresponding quantitative data. Future research could explore potential biases in perceptions by comparing project managers' views on specific projects with the quantitative data from those projects. Second, while our study attempted to triangulate data for schedule, staff, and costs, limitations in company data systems prevented access to information on errors, quality expectations (service capacity, service quality perceptions), and crucially, our core variables of relational capital and "cozy relationships." This lack of data presents a valuable opportunity for further research. Additionally, the inclusion of only one Agile project limits the generalizability of our insights. Future research could delve into the real-life differences in project development stemming from the absence of detailed plans inherent in Agile methodologies.

Our research focused on specific policy decisions adopted by Company A, providing valuable insights into relational capital in their context. However, this option is bounded by limited policy exploration: Future studies could investigate diverse policy combinations under various project scenarios to broaden the generalizability of findings. Some examples are:

- Exclusion of burnout-induced turnover: While justified due to Company A's low turnover rate, future models should consider this factor to explore the broader impact of prolonged overtime and work intensity on staff rotation.
- Limited focus on relational capital effects: Focusing primarily on "cozy relationships" limits the scope. Future research could integrate the diverse positive and negative effects of relational capital for a more comprehensive understanding.
- Underexplored impact of Desired Relational Capital: Further exploration of direct consequences arising from using "Desired Relational Capital" would broaden the range of strategies available to organizations.

Lastly, a limitation arises from the difficulty in measuring quality. Our decision to incorporate non-traditional quality metrics in project management poses challenges. We combined service quality literature (Parasuraman, Zeithaml and Berry, 1985) with system dynamics principles (Oliva and Sterman, 2010) to introduce quality measurements based on discrepancies between expected and actual outcomes. While this approach offered valuable insights, it also highlighted the need for empirical quality measurements. Future research should develop long-term approaches to track quality changes over time, a promising area for further exploration.

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