Managing Time Complexity through Agility: The Cases of Fujitsu's World Record and Four Fortune 500 Companies[1]

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ABSTRACT

In the globalized, turbulent, and rushed nature of contemporary work, organizations perceive an increasing pressure to master digital transformation. To do so, organizations are increasingly turning to 'high speed' methods such as *agile* and *flow*. We argue that the differentiating feature of these methods is how to address time complexity to increase time-to-delivery, epitomized by terms such as *cycle time*, *lead-time*, *latency*, *real-time*, and *velocity*. This emphasis on speed is often an over-simplification of many complex and multi-faceted time complexities in play, and such an obsession on speed alone often results in failure. We examine how Fujitsu succeeded in managing time complexity by keeping multiple temporal challenges imposed by different time conceptions, temporal interdependencies, and management styles in sync to set a Guinness World Record with the largest animated tablet PC mosaic. We compare our findings with four other Fortune 500 companies confirming that applying agile practices can help in managing time complexity.

KEYWORDS

Agile practices, agility, digital transformation, time complexity, time conceptions.

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Digital transformation is ubiquitous and companies of virtually all industries and sizes are under pressure to innovate on business models as new competitors create new digital products or services with the help of digital technologies. While startups or born digital companies like Amazon, Facebook or Google are agile by nature, established companies struggle with the question of how to react fast and flexibly to rapidly changing market environments. In consequence, many firms perceive the pace of change in the digital age and the significant increase of resulting challenges[3]. Established companies face a unique set of challenges when increasing speed and flexibility as they need to balance between 'keeping the lights on' with existing operations while simultaneously allocating sufficient resources (i.e., time and capacities) to innovate with digital technologies. In response, many companies are redesigning their digital strategy[4] and introducing agile practices and structures to increase speed and flexibility[5] ultimately addressing the multi-faceted aspects of time.

To increase flexibility and reduce time-to-market, companies need to manage time and its inherent complexity such as different time conceptions, temporal interdependencies and management styles. To do so, organizations and their employees need to perceive and experience time, as well as their relationship and interaction with time. This perception, the experience of time and the respective relationship with time are highly depended on a person's social context and on contingencies in an organizational setting resulting in a phenomenon we refer to as time complexity.

[3] Recommended references for challenges imposed by digital transformation are (1) Hess, T., Matt, C., Benlian, A., and Wiesböck, F. 2016. "Options for Formulating a Digital Transformation Strategy," *MIS Quarterly Executive* (15:2), and (2) Dixon, J. A., Brohman, K., and Chan, Y. E. 2017. "Dynamic Ambidexterity: Exploiting Exploration for Business Success in the Digital Age," in: Proceedings of the 38th International Conference of Information Systems. Seoul, Korea. Seoul, Korea: AIS.

[4] Good case studies on how to formulate a digital strategy include: (1) Sia, S. K., Soh, C., and Weill, P. 2016. "How DBS Bank Pursued a Digital Business Strategy," *MIS Quarterly Executive* (15:2), pp. 105-121, (2) Hansen, R., and Sia, S. K. 2015. "Hummel's Digital Transformation toward Omnichannel Retailing: Key Lessons Learned," *MIS Quarterly Executive* (14:2), and (3) Dremel, C., Herterich, M., Wulf, J., Waizmann, J.-C., and Brenner, W. 2017. "How AUDI AG Established Big Data Analytics in Its Digital Transformation," *MIS Quarterly Executive*, (16:2), 81–100.

[5] An overview of agile forms of organizational design at established companies including adoption paths can be found at: Gerster, D., Dremel, C., Brenner, W., and Kelker, P. 2020. "How Enterprises Adopt Agile Forms of Organizational Design: A Multiple-Case Study," *ACM SIGMIS Database: the DATABASE for Advances in Information Systems*, (51:1), pp. 84-103.

We use temporal research to examine how established companies manage challenges resulting from time complexity applying concepts such as clock time, event time, or time as cyclical pattern. The adoption of a temporal lens promises to enrich our understanding of strategic change inherent to digital transformation and can provide a deeper perception including potential conflicts among actors operating out of different time perspectives[6].

We examine how agile practices can help established companies in managing time complexity. We describe how Fujitsu set a Guinness World Record for the world's largest animated tablet PC mosaic on November 7, 2017. Extending and generalizing these findings, we present four comparative cases of Fortune 500 companies adopting agile practices to manage challenges imposed by time complexity. We conclude with providing managerial recommendations on how time complexity can be reduced by applying agile practices in today's turbulent times.

THE COMPLEXITY OF TIME

Digital transformation can be characterized by multiple complexity dimensions including structural complexity, uncertainty, ambiguity, dynamics, and pace[7]. From a practitioner's perspective, today's volatile and rapidly changing business world can be characterized as a conglomerate of complex business changes, situations, and decisions. This includes changes in the business environment through technological innovations or changing customer requirements, team and project dynamics, or regulatory changes. Accordingly, there is an immense need to handle multiple complexity dimensions to understand how an actor or a team responds to different complexity dimensions as teams develop and exist in a temporal context and work is planned and carried out in real schedules[8]: First, while uncertainty is inherent to innovation and novelty, it can be experienced as gap between the amount of available information and information which would be ideally required for decision making. Second, project dynamics may refer to project changes such as changes in requirements (or changes in

[6] A comprehensive literature review on time in strategic change can be found at: Kunisch, S., Bartunek, J. M., Mueller, J., and Huy, Q. N. 2017. "Time in Strategic Change Research," Academy of Management Annals (11:2), pp. 1005-1064.

[7] The following articles provide a review of complexity in projects: (1) Geraldi, J.; Maylor, H.; Williams, T. (2011). "Now, let's Make it Really Complex (Complicated): A Systematic Review of the Complexities of Projects", International Journal of Operations & Production Management 31(9): 966-990, and (2) Williams, T. (2005). Assessing and building on project management theory in the light of badly over-run projects. IEEE Transactions on Engineering Management, 52(4), 497-508.

[8] More on generic temporal problems inherent to collective action can be found in McGrath, J. E. (1990). Time matters in groups, Intellectual teamwork: social and technological foundations of cooperative work, L. In: Erlbaum Associates Inc., Hillsdale, NJ.

objectives caused by volatile market conditions or competitive pressure) and is highly interrelated with time uncertainty. Third, pace is an important complexity driver as urgency and criticality of time goals require different structures and managerial attention[9]. Finally, time complexity itself may result from temporal structuring like forming of a group (e.g., related to a group's lifecycle with the development stages forming, storming, norming, and performing[10]) and the temporal patterning of a group's actions caused by temporal ambiguity, conflicting temporal interests, requirement as well as the potential scarcity of resources[11].

As time is a common denominator of these complexity dimensions, we focus on time complexity as a key challenge imposed by digital transformation. For instance, the question how to respond readily to uncertain market environments changing in a high pace is heavily related to knowledgeably managing time complexity. Contrary, research and practice often emphasize a traditional clock view of time where technology implementation and value are often judged in terms of *speed*. Yet, time is an inherently complex, multi-faceted, context-dependent, and subtle concept and is by nature socially embedded – a phenomenon we refer to as time complexity. Time complexity results in situations where different temporal dimensions converge and need to be continuously identified and managed. While Information Systems (IS) practice and researchers often emphasize the impact of information technology on the speed of organizational and social life, IS research falls short to address the polymorphous, complex, and nuanced nature of time[12]. For instance, studies of project or organizational complexity tend to omit a temporal element completely or tend to focus on pace or speed as the single one-dimensional aspect of time complexity[13]. We argue that there is a need to look at the vast range of temporal complexities inherent to digital transformation. To do so, we develop a set of temporal complexities (see Table 1) to

[9] More on the complexity dimension pace can be found at: (1) Clift, T.B. and Vandenbosch, M.B. (1999), "Project complexity and efforts to reduce product development cycle time", Journal of Business Research, Vol. 45 No. 2, pp. 187-98, (2) Remington, K. and Pollack, J. (2007), Tools for Complex Projects, Gower, Burlington, VT. (3) Shenhar, A.J., and Dvir, D. (2007), Reinventing Project Management: The Diamond Approach to Successful Growth and Innovation, HBS Press Book, Boston, MA.

[10] A classic reference on the lifecycle of groups is Tuckman, B. W., & Jensen, M. A. C. (1977). Stages of small-group development revisited. Group & Organization Studies, 2(4), 419-427.

[11] McGrath, J. E. (1990). Time matters in groups, Intellectual teamwork: social and technological foundations of cooperative work, L. In: Erlbaum Associates Inc., Hillsdale, NJ.

[12] We recommend the following standard references on temporal theory and time complexity: (1) Nandhakumar, J. 2002. "Managing Time in a Software Factory: Temporal and Spatial Organization of IS Development Activities," The Information Society (18:4), pp. 251-262, (2) Saunders, C., and Kim, J. 2007. "Editor's Comments: Perspectives on Time," MIS Quarterly, pp. iii-xi, and (3) Shen, Z., Lyytinen, K., and Yoo, Y. 2014. "Time and Information Technology in Teams: A Review of Empirical Research and Future Research Directions," European Journal of Information Systems (24:5), pp. 492-518.

[13] Geraldi, J.; Maylor, H.; Williams, T. (2011) Now, let's Make it Really Complex (Complicated): A Systematic Review of the Complexities of Projects, International Journal of Operations & Production Management 31(9): 966-990.

provide practitioners with a model to think and engage with these temporal complexities related to digital transformation building on the foundational work of Ancona et al. (2001)[14].

Table 1. Classification of temporal complexities.

Dimension	Subdimension	Examples
1. Time conceptions	Types of time	Activities are structured around event or clock time
	Socially constructed time	Work organization (e.g., nine-to-five workdays), celebrations (e.g., public holidays)
2. Temporal interdependencies	Single work activities	Estimation, scheduling, rate of completion, and duration
	Repeated work activities	Cycle, rhythm, frequency, and interval
	Connecting work activities	Ordering or synchronization
	Changing or transforming work activities	Life cycles, jolts, interruptions, entrainment, and patterning
3. Temporal management styles	Temporal perception of work activities	Experience of time during work, time passing, time dragging, experience of duration or novelty
	Temporal personality of actors	Temporal orientation or temporal style of actors (e.g., preference for being early or late)

This set of temporal complexities provides a comprehensive and holistic analysis of temporality, thus synthesizing various temporal concepts across different areas of studies and provides a common framework for temporal constructs and variables[15], emphasizing social issues of temporality. We argue that a framework that places such emphasis on these issues is particularly suited to explore the complexities imposed by digital transformation.

Table 1 depicts three categories of time complexity, namely *time conceptions*, *temporal interdependencies*, and *temporal management* styles. All three dimensions are interrelated rather than mutually exclusive and are, thus, creating time complexity. The first dimension *time conceptions* refers to how time is structured and conceived. For example, one could organize time primarily by clock time[16], whereby one might set out a plan broken down by months or might require that a certain activity such as a release is done on a Friday. Likewise, a sprint of a defined length is related to clock time. Event time on the other hand organizes work around events and things that need to be achieved (e.g., the

[14] Ancona, D. G., Okhuysen, G. A., and Perlow, L. A. 2001. "Taking Time to Integrate Temporal Research," *Academy of Management Review* (26:4), pp. 512-529.

[15] More on the framework of Ancona et al. (2001) and how it relates to other temporal theories can be found at: Shen, Z., Lyytinen, K., and Yoo, Y. 2015. "Time and Information Technology in Teams: A Review of Empirical Research and Future Research Directions," European Journal of Information Systems (24:5), pp. 492-518.

[16] Mosakowski, E., and Earley, P. C. 2000. "A Selective Review of Time Assumptions in Strategy Research," Academy of Management Review (25:4), pp. 796-812.

release happens when all tests are passed regardless of what day, week, or month it happens to be). Complexity can be caused by inconsistencies or misunderstandings regarding the exact clock or event times being used, or when some teams or people are using clock time while others are structuring their work on an event time basis. Furthermore, complexities can be caused by socially constructed time and its impact on work organization (e.g., nine-to-five workdays or five workdays per week, public holidays (e.g., Easter, Passover)[17]). For instance, some may have very different expectations particularly around what overtime is expected and what public holiday times are sacrosanct. In today's world of global division, work complexity due to socially constructed time is omnipresent as there are often multiple teams from different countries and time zones, religions, and cultures working on the same project, while each acts with their own radically different norms and with their expectations of themselves and of each other's obligations.

The second dimension *temporal interdependencies* refers to how activities are mapped to time. We suggest that practitioners first of all analyze complexities inherent with *each single activity*. Even single activities may be complex in how they are estimated and scheduled, and how long they should take versus how long they actually take[18]. Then consider *activities which repeat* (e.g., sprints). Practitioners need to think about how frequently the activity should take place and how long the intervals between each should be. Creating a sustainable rhythm of activities can be inherently complex, and managing multiple, often conflicting rhythms even more so. We then suggest that one considers how *different activities should be temporally connected*. What order should they take place in? What happens when they cannot or do not run in this pre-ordained order and what complexities arise? Can and should they run simultaneously, should they be synchronized and how can the complexities in maintaining this synchronization be resolved? Finally, and probably most importantly, we suppose that not all activities adhere to the original plan, and thus suggest that practitioners examine the temporal complexities of changing activities. For example, there will be unexpected jolts and interruptions. A good process will pre-empt or at least address these when they occur. Teams often behave differently under time pressure and short deadline conditions, and so we suggest that one examines the complexities that

[17] Shen, Z., Lyytinen, K., and Yoo, Y. 2015. "Time and Information Technology in Teams: A Review of Empirical Research and Future Research Directions," *European Journal of Information Systems* (24:5), pp. 492-518.

[18] More on dimensions of world and their underlying aspects of organizational culture can be found at Schriber, J. B., and Gutek, B. A. 1987. "Some Time Dimensions of Work: Measurement of an Underlying Aspect of Organization Culture," Journal of Applied Psychology (72:4), p. 642.

occur during these extreme periods. These temporal interdependencies of activities like scheduling, synchronization, or task allocation can be perceived as a team's response to master challenges resulting from time complexity. It is easy to assess a process in a calm, quiet stage of the project. It is often at the times of crisis that one truly sees how well activities are synchronized and how well one is capable of managing time complexity.

The third dimension *temporal management styles* refers to how of actors perceive and respond to time. First, actors may perceive time in a multitude of ways. Also, they have temporal personalities – some may like to be put under time pressure and create outstanding results as the deadline approaches while others are incapable of coping with such pressure. Others may enjoy their temporal performance illustrated in dashboards or team story or sprint boards, others may not. Some depend on a sustainable work rhythm while others might be bored by it. An actor's relationship to time deeply varies among different cultures, sub-cultures, and personalities[19]. Generally, methods for managing time complexity are agnostic in this regard: They tend to ignore the diverse and multi-faceted complexities arising from temporal perceptions and personalities.

As digital transformation imposes the need to identify and readily respond to frequently changing market conditions, agility as organizational capability to continually sense environmental change and respond readily is of highest importance to almost any company[20]. Consequently, agility is a core capability to master challenges imposed by digital transformation. We argue that an important complexity driver for organizations today is time complexity while agility is a means to tackle new challenges which are imposed by an environmental change within an organization, altering the level of time complexity. While increasing agility is often superficially referred to as speed, the organizational capability to sense change and respond readily is by far more complex than just increasing speed, but as we argue, helps beyond others to address an increasing multi-faceted, time-complex digital world.

In the following we illustrate how Fujitsu experienced different dimensions of time complexity during their endeavor to set a Guinness World Record with the largest animated tabled PC mosaic. We extend

[19] Mosakowski, E., and Earley, P. C. 2000. "A Selective Review of Time Assumptions in Strategy Research," Academy of Management Review (25:4), pp. 796-812.

[20] A standard reference on enterprise agility as organizational capabilities to sense environmental change and respond appropriately is: Overby, E., Bharadwaj, A., and Sambamurthy, V. 2006. "Enterprise Agility and the Enabling Role of Information Technology," European Journal of Information Systems (15:2), pp. 120-131.

our findings with four case studies of Fortune 500 companies applying scaled agile practices to master time complexity challenges imposed by digital transformation.

THE FUJITSU CASE: MANAGING TIME COMPLEXITY TO SET A GUINNESS WORLD RECORD

In July 2017 Fujitsu started its journey towards setting a Guinness world record which targeted the composition of the largest animated tabled PC mosaic. This endeavor can be assessed with medium to high time complexity due to its highly challenging time frame, inherent technical complexity, and the scope of a single distilled activity (i.e., setting a world record).

Fujitsu is the leading Japanese information and communication technology (ICT) company and supports with approximately 132,000 employees its customers in more than 100 countries[21]. Fujitsu, in business since 1935, had highly optimized internal processes early on and therefore is accustomed to challenges inherent to an innovative endeavor like setting a Guinness World Record – a journey which combines both, technical complexity and novelty with an ambitious timeline. Consequently, it was initially far from obvious of whether Fujitsu would succeed especially when considering the remaining time of less than three months as Fujitsu's Head of Product IT in EMEIA noted:

> *"We have done something new, something disruptive, something completely different. And this is currently a real challenge especially for large, established companies in IT departments and business units" (Fujitsu Head of Product IT in EMEIA).*

The attempt was planned as part of a long-run traditional annual fair "Fujitsu Forum 2017" of the EMEIA region, consisting of the subregions Europe, the Middle East, India, and Africa, for its clients, partners, and prospects. With over 10,000 visitors from more than 80 countries, Fujitsu Forum is one of the largest customer events in the ICT industry[22]. Representatives of Fujitsu's EMEIA top 100 clients were invited to an exclusive dinner reception on the evening before the Fujitsu Forum 2017 – the "showtime" for setting Fujitsu’s Guinness World Record.

[21] More on Fujitsu can be found at Fujitsu's website: http://www.fujitsu.com/global/about/corporate/info/index.html.

[22] The website of the Fujitsu Forum 2017 has all information about the event, its agenda, speakers, presentations, and videos: https://www.fujitsu.com/de/microsite/forum-2017/.

To achieve this goal invited guests would get a tablet PC to place it afterwards in a specific order and to build together a huge screen consisting of a minimum of 220 animated tablet PCs to create the largest animated tablet PC mosaic. Though this might not sound overly complex at first glance, it turned out to be quite challenging: For instance, tablet PCs are computers and not monitors, and therefore, need to be modified to display a dedicated part of an animated mosaic or to prevent unwanted notifications on antivirus, firewall, Windows updates or Wi-Fi settings.

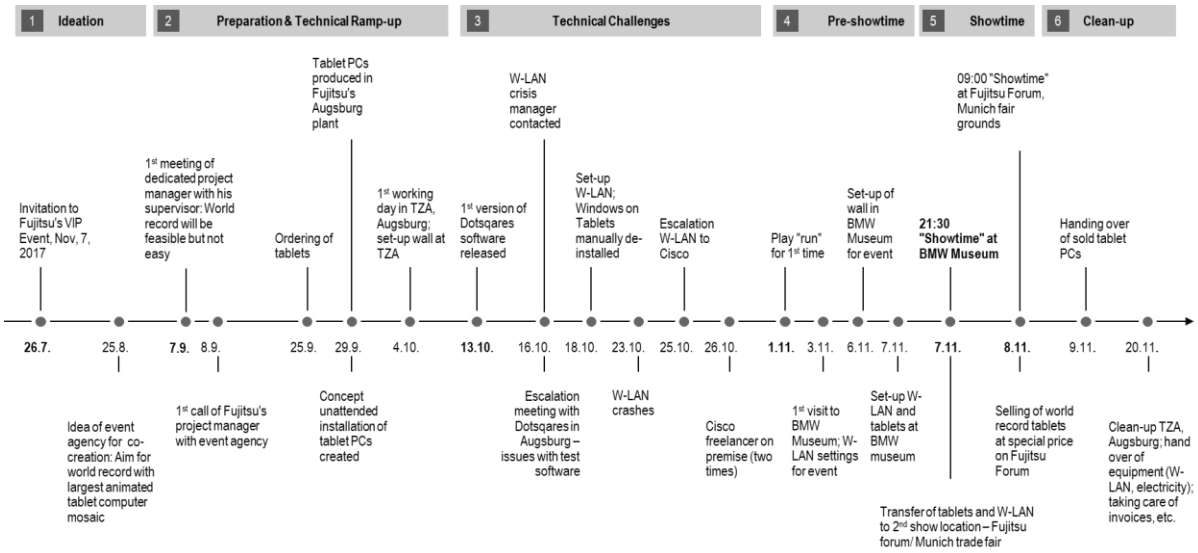
Beyond the successful management of time complexity, namely considering the diverse time conceptions of involved contributors, time interdependencies during the attempt as well as temporal management styles of the project lead and Fujitsu's management were a key success factor.

How to Eat an Elephant? The Importance of Time Slicing and Continuous Improvement

An evolving step-by-step approach allowing for failure, incorporating instantaneous feedback, and continuous optimization has been applied by Fujitsu to manage different time complexity dimensions. Fujitsu purposefully addressed key dimensions of time complexity through instantiating a project lead who knows how to address a definite event time (i.e., 'showtime' of the Guinness World Record), slicing available time, and freeing up resources to make best usage of available time and to avoid potential productivity limitations resulting from socially constructed strict and inflexible working schedules.

Figure 1 shows the different project phases. The subsequent section briefly describes key chronological events illustrating challenges emerging from the different dimensions (i.e., time conception, temporal interdependencies, and temporal management style) of time complexity involved.

Figure 1. Overview of key project phases and timeline.



Phase 1: Ideation

The first phase, ideation, lasted from July 26, 2017 to August 31, 2017. Invitations to Fujitsu's dinner reception guests were sent out on July 26, 2017. In light of the preparation of the dinner reception, the idea of setting a Guinness World Record with the world's largest animated tablet PC mosaic was created by an event agency engaged by Fujitsu to host the dinner reception. The initial idea was that the event agency takes care of the world record attempt. Consequently, Fujitsu did not engage actively in the realization of the world record endeavor and was on hold reacting only to the event agency's requests.

Phase 2: Preparation and Ramp-up

The second phase, preparation and ramp-up, lasted from September 1, 2017 to October 11, 2017. Already during this phase, initial time complexity challenges emerged. For instance, one question was how 250 tablet PCs (including spares, development, and test devices) cloud be manufactured without the usual production lead time as Fujitsu builds to order only. Furthermore, on a technical level the handling of the time lag of signals transferred via Wi-Fi to the tablet PCs and the synchronization of each single device to create a fully synchronized mosaic display across all devices turned out to be especially challenging requiring a proper signal synchronization.

Within this phase a turning point is acknowledged as the perceived progress was not in line with Fujitsu's expectations. In consequence, Fujitsu took over sole responsibility for the endeavor to set a Guinness World Record in early September with just less than two months remaining. Due to time criticality,

Fujitsu appointed a small team including a fully dedicated project lead endowed with extensive powers. Fujitsu's project lead formulated two conditions as prerequisites for his engagement: First, relief of all other duties with 100% time dedicated to the project. Second, a 'flexible budget' to circumvent existing (non-agile) processes as there would be no time to follow regular processes in place at Fujitsu, related for instance to purchasing or approval processes. Fujitsu's small project team consisted of just two full-time team members and three part-time student helpers besides of various colleagues involved ad-hoc for specific tasks and, in total, 13 external partners.

Right from the beginning, the project team focused on getting everything accomplished until Fujitsu's key event time – the 'showtime' of the Guinness World Record attempt. The remaining time of this phase was used for planning, preparation, and ramp-up of the involved components for the world record attempt imposing challenges regarding appropriate timing of various activities due to novelty and a lack of experience with comparable endeavors. For instance, the synchronization of Wi-Fi lags for achieving a seamless display of the mosaic across all tablet PCs could be sorted out with the help of an Indian software company. Further, a location for the installation of a test wall for ensuring the readiness for 'showtime' could be identified at a science park nearby Fujitsu's Augsburg plant.

Phase 3: Technical Realization and Challenges

The third phase, technical realization and challenges, lasted from October 12, 2017 to October 26, 2017. Wi-Fi was up running and an initial version of the software for the video app was available for testing by mid-October. However, several unexpected jolts and interrupts occurred, for instance, related to Wi-Fi connectivity as the quality was perceived as poor regarding the synchronization of pictures and significant time lags for transmitting signals occurred. One of the three brand-new Wi-Fi routers had been identified as not working properly, i.e., disturbing the signals of the two other Wi-Fi routers through generating noise, and was consequently replaced with an old and well-functioning back-up Wi-Fi router. After this issue was successfully resolved on October 25, the animated mosaic was tested for the first time. All devices revealing further issues with poor synchronization of pictures causing defects in the correct display of the mosaic had to be fixed successively by the software provider.

Phase 4: Pre-Showtime

The fourth phase, pre-showtime, lasted from October 27, 2017 to November 6, 2017. With less than two weeks to showtime, a software update correcting wrong content display allowed the animated tablet PC mosaic to be displayed seamlessly for the first time on November 1, 2017. This resulted in some spare time for conducting small software refinements, logistics planning, packing of the tablet PCs and visiting the event location at the BMW Museum in Munich. The show wall, featuring no power supply and minimum gaps between the tablet PCs, was set-up in the BMW Museum on the day of the event.

Phase 5: Showtime

The fifth phase, showtime, lasted from November 7, 2017 to November 8, 2017. As part of the VIP dinner event on November 7, 2017 at the BMW Museum, the tablet PCs were handed out to the guests just shortly before showtime and guests were asked to put the tablet PCs to a designated grid position on the show-wall. A maximum of three attempts for the animated tablet PC mosaic was granted and supervised by representatives of the Guinness World Record committee. After all tablet PCs were placed by the event's guests at their dedicated position, an initial test revealed that all tablet PCs except for three devices had connectivity and responded accordingly. Due to the profound trouble shooting expertise gained earlier, the problem's root cause was identified quickly: Two tablet PCs were connected erroneously to the BMW Museum's Wi-Fi hotspot and the third device was manually turned onto flight mode.

After manually correcting the settings of these three devices, the animated tablet PC mosaic was displayed on all 220 tablet PCs correctly, resulting in setting the Guinness World Record for the largest animated tablet PC mosaic on November 7, 2017, by Fujitsu[23]. Picture 1 shows the animated tablet PC mosaic at BMW Museum on the day when Fujitsu set the Guinnes World Record.

[23] An event video documenting the first successful Guinness World Record attempt during the VIP dinner event is available on YouTube: https://www.youtube.com/watch?v=mzrfKUqQgws.

Picture 1. Event location BMW Museum Munich, Germany, on Nov. 7, 2017. The left picture displays the installation of the tablet PC mosaic by Fujitsu's VIP clients and the right picture shows the animated tablet PC mosaic.

Phase 6: Clean-up

The final phase, clean-up, lasted from November 9, 2017 to November 21, 2017. Due to the focus on bringing the tablet PC mosaic to life, everything else that could have been postponed like commercial topics with providers was postponed after the event. On November 21, 2017, the de-installation of the training wall including the cleaning of the location took place, and rented electricity equipment and Wi-Fi routers were returned.

Challenges Related to Time Complexity

1. Time Conceptions

Fujitsu was exposed to all types of time conceptions, specifically, the time types clock time, event time, and socially constructed time. Once the decision was made that Fujitsu assumes responsibility for setting the Guinness World Record, available remaining time had been divided into small chunks and high-level milestones were identified. By de-coupling time into small pieces, available (clock) time could be allocated most effectively. Fujitsu treated the date for the VIP event, entitled internally as "showtime", as an irrefutable deadline until which everything required for setting the Guinness World Record needed to be in place. To master the ambitious timeline, Fujitsu had at the same time to remain flexible with solution design and to allow for compromises as long as basic functionalities (i.e., defined minimum requirements to set a Guinness World Record) were to be achieved. In this respect, the concept of event time was important to Fujitsu as the entire project planning, status tracking, and progress reporting almost exclusively focused on the day of the VIP event.

Furthermore, Fujitsu was exposed to time aspects of socially constructed work organization: Fujitsu gave complete freedom to the project team regarding work organization despite of its employees having a regular weekly 40 hours working contract. Consequently, the team decided not to stick to the usually applied fixed working day schedule Monday through Friday, but rather to proceed on a needs basis as project progress and critical activities like trouble shooting required. To do so, the project team had full flexibility to explore their own and perceived as best-suitable working schedule. This resulted even in working at night or on weekends while at the same time taking time off during the day on weekdays to compensate for night shifts. To organize work accordingly, a small core team consisting of fully dedicated, self-confident, and empowered individuals was essential to Fujitsu's success. This approach allowed to keep the team-internal alignment and communication to the absolute minimum.

2. Temporal Interdependencies

To set the Guinness World Record, Fujitsu had to master complexities resulting from multiple temporal interdependencies: Mapping of single and repeated work activities, connecting and synchronizing different work activities, managing interdependencies, and changing or transforming work activities in the case of jolts or interruptions.

Fujitsu applied three approaches for mapping single work activities to time: A high level estimation to completion, scheduling of activities according to available time, and applying a "fail fast – fail often" approach to make most efficient usage of time. Regarding the estimation to completion, a rough idea on general feasibility gave the team convidence that it was possible to set the Guinness World Record given the ambitious timeline and related circumstances:

> *"I knew that it could work – otherwise I wouldn't have accepted this assignment. I had to know the involved components and to know of how they could be provided" (Project Manager Fujitsu).*

Fujitsu applied a sequential planning of activities to available time to limit the number of potential sources for errors and to reduce complexity of interrelated work packages. Furthermore, this approach has been chosen because a traditional approach to project planning with a detailed initial planning of activities was simply not feasible due to the lack of comparable experience and applicable knowledge for such an endeavor:

> *"I initially tried to draw a Gantt-chart but realized soon that this chart requires more time in drawing than it provided benefits. I only could do one step after the other, as circumstances and priorities changed rapidly" (Fujitsu's Project Manager).*

In consequence, it was mandatory to develop specifications successively and to plan and proceed step-by-step in small iterations once single activities were completed successfully. With this approach, detailed specifications were developed subsequently in sprints along with the implementation, a vital component of mapping single activities to work time for Fujitsu. Additionally, a "fail fast – fail often" approach in conjunction with even provoked failure had been applied. This approach allowed to test possible solution components and to explore issues and limits at an early stage. Exemplarily, one of the key challenges was the synchronization of single tablets to create a seamless display of the mosaic across all tablet PCs with a custom-made software. While initial results were poor due to wrong ratios of the mosaic pieces, the result could be successively improved by trial and error in iterations between the team and the Indian software provider.

To map repeated work activities and to provide a structured approach on how to develop, test, and continuously improve features, Fujitsu proceeded in sprints of a defined length of two weeks. This repeated rhythm provided a clear structure of available (clock) time. Related work packages had to be adjusted to be feasibly completed within a sprint's length, thus, limiting the available time for a specific feature or for specific activities like solution development, programming, testing and the like. To make most efficient use of the available time, Fujitsu even partly adapted the approach of strict time slicing when planned activities were completed or when technical challenges or hurdles required immediate attention. With this approach, Fujitsu even stopped a sprint if hurdles required special attention. Exemplarily, Fujitsu immediately stopped a started sprint as soon as troubles with interfering Wi-Fi signals occurred and focused on isolating potential sources of errors to identify the root cause.

To connect different work activities, Fujitsu applied time allocation to create an order, synchronization or interdependencies and relocation of activities, i.e., the re-scheduling of an activity: To allocate available time most effectively, Fujitsu focused on essential business requirements, i.e., minimum requirements for setting the Guinness World Record.

One important decision regarding the ordering of work activities was to separate the vision for setting a Guinness World Record from its realization: Fujitsu took over the lead for technical realization from the marketing agency who created the idea after almost two months have passed by without satisfying

progress or results. While Fujitsu focused on overall feasibility and coordination of activities, details of solution design and realization were left up to specialists. This approach of involving specialists helped to remain flexible with solutioning and required rescheduling of activities in case of jolts. The relocation of activities was particularly challenging because of a total of 13 involved external partners requiring overall steering and management of interdependencies. The wide range of external partners resulted from covering specific aspects of solution design ranging from providers of hard- and software and providers of connectivity or power supply to specialists for designing fair booths like video animation on tablet PCs where Fujitsu had no own expertise. Consequently, the relocation of activities to external partners avoided resources conflicts and leveraged Fujitsu's comprehensive partner ecosystem most effectively as Fujitsu soon realized that established and readily workable relationships to a diverse set of expert partners could save valuable time[24].

Related to changing or transforming activities, jolts and interrupts stroke Fujitsu soon after the decision to take on responsibility for the technical realization of the Guinness World Record attempt: Exemplarily, the question of how to get 250 tablet PCs manufactured on short notice without interference of the regular PC production had to be resolved. Usual production lead time would be several weeks as Fujitsu builds to order only. As one approach to address jolts and interrupts, Fujitsu relied on solution components that had already proven to be successful, and thus, helped in speeding up realization. Fujitsu experienced this with the latest but untested Wi-Fi routers that were chosen initially: After causing significant trouble, these brand-new devices had been replaced by old routers that were usually used as back-up devices for events. With this approach, Fujitsu immediately stopped trouble shooting once it turned out that the signal noise was generated by one of the routers but decided to employ a technically suboptimal but workable solution with spare routers and thus, saved valuable time. Likewise, Fujitsu was exposed to midpoint transitions, i.e., a change of activities after some midpoint: After initially relying on the external marketing agency for solution development exclusively, Fujitsu realized almost two months after ideation that the achieved progress was not in line with Fujitsu's expectations and, thus, decided to assume overall responsibility for the world record endeavor.

[24] The section entitled "Overview of partners and architecture involved" in the Appendix further describes architectural solution components and involved external partners.

3. Temporal Management Styles

Temporal management styles were vital to Fujitsu as the event date on November 7, 2017 was omnipresent. Temporal perception is related to the experience of time, time passing, duration and novelty. This perception of novelty was vital as it helped to form a team identity based on this ambitious and disruptive endeavor. Particularly, temporal perception with Fujitsu's VIP dinner event as an irrefutable deadline that cannot be influenced, changed, or delayed was essential in keeping in sync all activities required for on-time completion. Being a hobby lighting designer for concerts, Fujitsu's project manager was fully aware of the concept of 'showtime':

> *"There is a fixed date and time called 'showtime' with a precisely defined starting time until that everything needs to be completed and up running" (Fujitsu Project Manager).*

This experience of time as an irrefutable deadline helped to set priorities right from the beginning in receiving the required freedom regarding decisions and endowments. Likewise, Fujitsu experienced time passing regarding the initial project progress that led to Fujitsu assuming responsibility for the world record endeavor. The experience of duration and novelty was associated with the entire endeavor and was perceived by team members right from the beginning:

> *"It was the spirit that was new to us: We had this showtime and we had not discussed what could go wrong" (Project Team Member Fujitsu).*

This experience of novelty helped the team to form an own identity and team spirit as additional source for energy and motivation to handle challenging situations. Temporal orientation and management styles could also be observed regarding individual leadership styles in response to management challenges caused by temporal complexities to achieve an ambitious goal under challenging conditions: Fujitsu's management clearly committed to the initiative by entitling the project lead with comprehensive endowments to temporally by-pass existing rules and procedures to speed up processes. Furthermore, a credible commitment that failure had no negative consequences was helpful as it gave the team the required freedom for experimentation and invention of innovative solutions.

On team level, the project lead applied a temporal management style in response to specific challenges regarding applying a direct and pro-active communication between team members, external partners, and Fujitsu management:

"Agility is result of immediate action. I preferred personal talks to e-mails to immediately address challenges and needs of key stakeholders" (Project Manager Fujitsu).

Table 2 summarizes measures applied by Fujitsu to handle time complexity caused by different time types.

Table 2. Measures for addressing different time types as applied by Fujitsu.

Dimension	Subdimension	Recommended measures
1. Time conceptions	Types of time	– Allocate high-level milestones within available clock time. – Allocate time to chunks of a defined length (i.e., sprints). – Focus on the deadline with a defined minimum functionality and adapt available time accordingly.
	Socially constructed time	– Allow for a flexible working schedule rather than usually applied working schedules to reflect the project needs.
2. Temporal inter-dependencies	Single work activities	– Replace detailed advance-planning by an initially high-level feasibility assessment. – Specify requirements successively during implementation. – 'Fail fast – fail often' approach with even provoked failure.
	Repeated work activities	– Apply iterative sprints for gradual solution improvement.
	Connecting work activities	– Leverage specialists for relocation of work activities in case of unexpected challenges.
	Changing/ transforming work activities	– Rely on tried and tested approaches to address jolts or interrupts.
3. Temporal management styles	Temporal perception of work activities	– Perceive showtime as irrefutable deadline.
	Temporal personality of actors	– Apply a direct and personal communication style – Credibly commit that failure has no consequences.

Summarizing the above aspects, Fujitsu succeeded in setting a Guinness World Record with the largest animated tablet PC mosaic by managing different time concepts, temporal interdependencies, and different temporal management styles. As each single task required to set the Guinness World Record might be manageable, the complexity of the very different time concepts applicable to Fujitsu made the overall goal ambitious as Fujitsu's Head of Product IT in EMEIA noted:

"This is not going to be easy – there are so many bits and bytes that need to work seamlessly in sync together – this hasn't been done yet".

How Managing Time Complexity Helped Fujitsu to Set a Guinness World Record

To set the Guinness World Record, Fujitsu had to manage and synchronize different aspects of time including different time conceptions, temporal interdependencies, and temporal management styles resulting with medium to high time complexity due to the following reasons: (1) The overall timing related

to the unnegotiable date of the VIP dinner event on November 7, 2017 was especially ambitious as the initial approach of the event agency turned out to be not feasible because more than half of the time had already passed by. (2) The in total three different locations caused specific temporal interdependencies: As the event location at BMW Museum is a museum open to the general public on six days per week, installation, and testing of the show wall had to be accomplished within just hours before the event to avoid interference with the museum's regular opening hours. Likewise, the show wall had to be de-installed and transported immediately after the VIP dinner event at BMW Museum to the location of the Fujitsu Forum 2017 (Munich fair grounds), re-installed and tested before Fujitsu Forum 2017 opened at 09:00 am again within less than eight hours. The different locations in combination with the very tight timing left almost no spare time between scheduled events. (3) Due to time pressure, technological novelty, and complexity of single tasks to be completed, Fujitsu had to leverage 13 external partners. While the partners on the one hand contributed with their skills and expertise, the steering of them caused additional complexities regarding timing of the work packages, interdependencies, or frictions in case of technical hurdles.

Despite that, mastering the *deadline of the event* was critical. Managing different and multiple facets of time complexity caused much more challenges than ‘just’ meeting an ambitious deadline. The different aspects of time that had to be managed and kept in sync simultaneously reflect the complexity of the endeavor to set a Guinness World Record with the largest animated tablet PC mosaic.

HOW APPLYING AGILE PRACTICES HELP IN MANAGING TIME COMPLEXITY

This section introduces comparative cases of four Fortune 500 companies exposed to different time complexity challenges. While for some companies the time-related challenges are obvious – for instance, a fixed planned date for a product market launch – other cases involve multiple less obvious time complexity challenges imposed by digital transformation. Examples include the need to reduce the number of unsuccessful projects to optimize the rate of completion, the adaption to frequently changing market conditions, or the increase of competitive advantage in response to competitive market entries. After a short introduction to the initial situations of the comparative case study companies we illustrate the resulting time complexity challenges to enrich our findings from Fujitsu.

Introduction to Comparative Case Study Companies

The first two case study companies, AviationCo and CommunicationCo, were formerly state-owned European companies and in business for more than 90 years exceeding 30,000 employees (AviationCo), and respectively for more than 20 years exceeding 210,000 employees (CommunicationCo). Table 3 lists further company details.

Table 3. Overview comparative cases AviationCo and CommunicationCo as of 31.12.2019.

	AviationCo	CommunicationCo
Industry	Airline	Telecommunications/ IT services
Age [years]	90+	20+
Employees [#; '000]	30+	210+
Key challenges	Eliminate bottlenecks to reduce cost of delay; shorten time-to-market	Reduce the number of unfinished projects; increase delivery speed
Applied scaled agile framework	SAFe	SAFe
Type of unit	Business	Business
Employees in agile unit [#]	Approx. 800	Approx. 12,500

AviationCo primarily aimed at finding ways to increase organizational flexibility and speed. Likewise, CommunicationCo also aimed at increasing speed and flexibility but focused especially on reducing the number of unfinished projects causing delays in customer delivery and customer dissatisfaction:

> *"It is like if the boat was still in the harbor because someone was missing, but everybody else was in perfect position and if we would have gone out, we would have rowed perfectly" (Product Owner, CommunicationCo).*

Contrary, AviationCo as a leading European airline and aviation pioneer, struggled with fostering innovation. Exemplarily, as an airline's organization is inclined to reflect hierarchical structures applied in the cockpit consisting of routines, checklists, clearly defined procedures, and chain of command, allowing for an error culture is especially demanding:

> *"We don't want the pilot to test of whether it makes sense to land without the landing gear extended. Consequently, an error culture at an airline is not a question per se, but rather a question of how to establish a learning culture allowing for mistakes where there are no negative consequences" (Director Digital Innovations, AviationCo).*

The remaining two comparative case study companies, AutomotiveCo and BankCo, are stock-listed companies. AutomotiveCo is a leading car manufacturer in Germany in business for more than 100

years exceeding 130,000 employees and BankCo is a European direct bank with a country subsidiary exceeding 5,000 employees and in business for more than 50 years. Table 4 lists company details.

Table 4. Overview comparative cases AutomotiveCo and BankCo as of 31.12.2019.

	AutomotiveCo	BankCo
Industry	Automotive	Financial services
Age [years]	100+	50+
Employees [#; '000]	130+	5+
Key challenges	Manage technical innovation in the context of unclear requirements under high time pressure	Increase customer centricity; reduce organizational complexity
Applied scaled agile framework	LeSS	Own framework (best of breed)
Type of unit	Business (car development)	Business (entire company)
Employees in agile unit [#]	Approx. 1,100	Approx. 4,800

AutomotiveCo and BankCo differ from AviationCo and CommunicationCo regarding being exposed to multiple dimensions of high time complexity: AutomotiveCo and BankCo aimed at increasing customer centricity and organizational innovation to defend their market position as innovation leaders against tech-companies like Apple or Google becoming increasingly active in innovation topics such as autonomous driving or electromobility (in the case of AutomotiveCo) or FinTech disrupting the financial services industry (in the case of BankCo). Consequently, the primary challenge related to time complexity for both companies was to innovate to maintain and defend their competitive edge. AutomotiveCo's car development unit responsible for establishing autonomous driving capabilities was exposed to multiple challenges related to time complexity: Technological novelty (i.e., autonomous driving or machine learning) and hurdles (i.e., analysing data volumes of up to 200 Petabyte) with frequent changes or unclear regulatory requirements in combination with an ambitious timeline (i.e., start of serial production of high autonomous driving features[25] planned for 2021) and a complex organizational setting involving feature teams provided by cooperation partners or even competitors consisting of suppliers and other car manufacturers.

Like AutomotiveCo, BankCo aimed at adopting scaled agile practices due to high time complexity within their market environment: BankCo, being a direct bank, was successful right from the beginning and

[25] High autonomous driving refers to a state where the mind is off according to the SAE's definition (https://www.sae.org/standards/content/j3016_201401/).

had a reputation for disrupting established banks. However, BankCo felt the need to react to the increasing competition from FinTech and to defend its competitive edge as competitors gained speed. In consequence, all four comparative case study companies have been exposed to different time concepts causing specific challenges related to time complexity which are described subsequently.

Challenges Related to Time Complexity at Comparative Cases

1. Time Conceptions

Similar to Fujitsu, the time types clock time or event time were important time conceptions also at the comparative cases. Exemplarily, event time was important for AutomotiveCo with an intended start of serial production of autonomous driving cars in 2021 causing high time pressure on development efforts. In consequence, all activities had to be scheduled and synchronized to match this targeted date for product launch. All four comparative case study companies also applied clock time regarding slicing (i.e., allocating short time cycles (sprints) of a defined length to available time).

Socially constructed time was observed regarding how to organize work and was especially present at AviationCo, AutomotiveCo, and BankCo: While AviationCo aimed at reducing the importance of hierarchies, AutomotiveCo collocated all resources from the corresponding car development units working on autonomous driving at the so called Autonomous Driving Campus to foster physical interaction of teams working together and to prevent potential frictions resulting from collaborating employees scattered at different work locations. To complement the physical collocation of resources, AutomotiveCo introduced more flexible working time concepts addressing especially the needs of a primarily young work force of IT professionals including regular home-based work for activities requiring no interaction with colleagues to compensate for the remote location of the new Autonomous Driving Campus. Likewise, at BankCo, the re-organization according to an agile structure comprised the entire organization as the CEO wanted to prevent frictions resulting from different (socially constructed) working styles of agile teams collaborating with non-agile teams:

> *"We have realized that the entire organization has to work agile and not just parts of it as frictions resulting from two different working styles were too big" (Product Owner, BankCo).*

2. Temporal Interdependencies

Time complexities resulting from temporal interdependencies could be also observed at the comparative cases. In a similar vein to Fujitsu, the simultaneous occurrence of multiple time concepts caused challenges resulting in high time complexity as multiple time dimensions needed to be managed simultaneously. Observed temporal interdependencies challenges were as follows:

Regarding the mapping of single work activities, AutomotiveCo had to ensure that the product launch for autonomous driving intended for 2021 could be achieved. CommunicationCo applied scheduling of product development according to SAFe[26] to facilitate that projects could be finished, and customer requirements could be met. As with Fujitsu, AutomotiveCo and BankCo replaced detailed advance-planning by a high-level planning and subsequent detailing during implementation. AutomotiveCo excelled in specifying requirements from a functional perspective only to give IT providers a maximum degree of freedom regarding implementation. Further, scheduling and mapping of repeated activities according to sprints took place at all comparative case study companies to slice available time with slots of a defined length:

> *"We realized that a classical project setting was not helpful for what we were doing and that it is much better to proceed in short, interactive cycles" (Agile Coach AviationCo).*

This allocation of the available time according to sprints provided a fixed structure and rhythm for development and improvement cycles of defined length. By this approach, the value generated in a given time slot could be increased and gradual improvement from sprint to sprint facilitated continuous improvement and allowed to incorporate early customer feedback.

The mapping of repeated activities could be observed regarding the allocation, ordering, or relocation of activities: Area product owners played an important role in allocating activities from the backlog to sprints as well as resources and for relocating in case of conflicting priorities, challenges or hurdles. BankCo for instance relocated previously conflicting activities by reorganizing the entire company according to agile structures. Thus, previously conflicting objectives and working styles resulting from the collaboration of agile and non-agile units could be removed. These renewing cycles for continuous improvement of features were especially important to CommunicationCo to reduce the number of errors and unfinished products. Likewise, AutomotiveCo applied feature enhancements with bi-annual

[26] More on SAFe can be found at: ScaledAgile. 2017. "Essential SAFe 4.5." Retrieved 29.10.2017, from http://www.scaledagileframework.com.

release bundles with software updates being deployed continuously over the air. Regarding connecting different activities, all four Fortune 500 companies applied feature backlogs where feature prioritization was done by the responsible product owner. In detail, a strict ordering of activities was critical for AutomotiveCo and CommunicationCo as was rapid development of new features due to interdependencies between single activities.

Changing or transforming activities could be observed at the comparative cases related to life cycles, midpoint transitions, jolts, and interrupts: Life cycles played an important role for AutomotiveCo as the development of autonomous driving capabilities required rapid improvement and optimization of sensors, lidar, and cameras involved to provide the required capabilities. Midpoint transitions could be observed at AutomotiveCo related to the bundling of all required resources in one unit and the physical collocation of all involved resources at a newly created autonomous driving campus or the joint decision to follow a standardized development toolchain fostering cross-team collaboration. As the area product owner points out, AutomotiveCo perceived the need to entirely transform the work organization of the autonomous driving unit to foster collaboration and innovation:

> *"We wouldn't have achieved such an ambitious objective with the traditional approach" (Area Product Owner AutomotiveCo).*

AutomotiveCo was also exposed to frequent jolts and interrupts when deploying new sensors which repeatedly caused significant delays. Similarly, CommunicationCo struggled with jolts caused by challenges to connect large legacy systems containing customer master and invoicing data required for the provision of new features:

> *"We have developed too many years on existing systems and have missed the point where tearing down and rebuilding would have been better" (Product Owner CommunicationCo).*

3. Temporal Management Styles

Temporal perception and management styles could be observed at all comparative cases. Temporal perception was critical for BankCo as it perceived a lack of speed when reacting to emerging competition from FinTech that was perceived to realize and respond to customer demands quicker:

> *"We as a bank are the elephant that has to keep up with the greyhounds of the FinTechs. FinTechs are fast, modern, innovative and customer-oriented and can realize customer requirements quickly. We have been very successfully for the last years making it difficult for the ordinary employee to understand why we need to change something" (Product Owner, BankCo).*

Likewise, CommunicationCo perceived a lack of speed regarding organizational decisions that were perceived as taking too long:

> *"The challenge was that we had become too rigid, too inflexible, too slow and too expensive. We have developed too many years on existing systems and have missed the point where tearing down and rebuilding would have been better" (Product Owner, CommunicationCo).*

Similarly, the experience of novelty could be observed at all comparative cases as the reorganization to fully agile structures along with the adoption of scaled agile practices were perceived as a significant change in working style, collaboration, and allocation of resources and in particular available time.

Temporal orientation and style, the characteristic in which an actor perceives, interprets, uses, allocates or otherwise interacts with time proved to be important for all cases: At BankCo, the CEO sponsored and personally supervised the agile transformation of the entire organization to face the imminent change to react timely and use time resources adequately. Likewise, at AutomotiveCo the division head initiated and supervised the collocation of all autonomous driving resources at the centralized autonomous driving campus as he was convinced that traditional approaches of organizing work were not feasible anymore to allow for an effective use of time and resources.

Similarly, the management style played an important role at AviationCo during the organizational transformation as the company had to foster the learning from errors in non-safety critical areas:

> *"The only mistake a company can make is not learning. There are actually no mistakes, only the possibility to learn" (Agile Coach, AviationCo).*

How Managing Time Complexity Helps in Reducing Time-to-Market and Increasing Customer Centricity

To master challenges resulting from high time complexity (i.e., situations where time pressure is high and where different, partly conflicting time dimensions occur simultaneously), all four comparative case study companies applied scaled agile practices[27] selectively. AutomotiveCo chose LeSS[28] whereas

[27] According to Dikert et al., scaled agile structures consist of at least 6 feature teams respectively 50 team members where each feature is responsible for a product that is managed by a corresponding product owner: Dikert, K., Paasivaara, M., and Lassenius, C. 2016. "Challenges and Success Factors for Large-Scale Agile Transformations: A Systematic Literature Review," Journal of Systems and Software (119), pp. 87-108. Good summaries and comparisons of the different scaled agile frameworks include: (1) Conboy, K., and Carroll, N. 2019. "Implementing Large-Scale Agile Frameworks: Challenges and Recommendations," IEEE Software (36:2), pp. 44-50, and (2) Kalenda, M., Hyna, P., and Rossi, B. 2018. "Scaling Agile in Large Organizations: Practices, Challenges, and Success Factors," Journal of Software: Evolution and Process (30:10), p. 1954.

[28] A good description of the scaled agile framework LeSS can be found at: Larman, C., and Vodde, B. 2017. "Less.Works." Retrieved 19.4.2018, 2018, from https://less.works/less/framework/index.html.

BankCo decided not to follow a standard framework for scaled agile but rather adopted an own internally developed framework integrating best practices from various frameworks. Consequently, AutomotiveCo and BankCo adopted scaled agile practices organization-wide (BankCo) or department-wide (AutomotiveCo) with the CEO (BankCo) or department-head (AutomotiveCo) as sponsor. Implementation took place at both companies with a time-boxed approach in waves with a total duration of 18 months (BankCo) and respectively 9 months (AutomotiveCo).

In detail, AutomotiveCo and BankCo aimed at creating transparency on the contribution of single tasks and dependencies between squads, feature teams or tribes. Continuous improvement aimed at the product, process, or organizational level. Regarding structure, focus was on establishing a matrix structure with product-orientation on the vertical and a professional or technical focus was set on the horizontal axis. Agile roles were defined on multi-team level and agile routines were used for repeated activities like quarterly business reviews for product planning.

All four comparative case study companies applied scaled agile practices with iterative delivery cycles of a defined length (sprints). With the approach of a fixed time and effort of feature teams towards sprints, scope and value are a deriving result. In consequence, the implementation of requirements as defined by the product owner can be achieved with minimum resources and time. Contrary, an agile approach does not require an initial specification of requirements as features are defined successively based on the product manager's prioritization during the sprints. Likewise, the need for innovation requires an incremental approach.

Further, AviationCo and CommunicationCo chose a unit-wide scope for adopting scaled agile practices with a dedicated team assuming the transformation lead. The corresponding team size and constitution varied with implementation scope. Each feature team consisted at least of one transformation lead, one agile coach, and one scrum master. AviationCo and CommunicationCo chose a stepwise and iterative implementation approach to mitigate risks of a big-bang adoption of the scaled agile framework SAFe. AviationCo and CommunicationCo aimed at reflecting essential agile principles: Transparency, continuous improvement, result ownership, and customer-centricity. Transparency was intended to be achieved by a clear allocation of products to dedicated units and by examining time interdependencies between feature teams and current challenges preventing a prompt delivery. For internal processes or structures, continuous improvement had been achieved with repeating and structured customer-facing and non-customer-facing meetings reflecting on success stories and areas for improvement.

Both, AviationCo and CommunicationCo applied a cyclical pattern of repeated activities, i.e., agile sprints to map activities to a fixed period of time. Both companies followed a demand-driven approach transforming volunteering teams with no strict implementation timeline but a clear scope for time chunks (i.e., sprints). CommunicationCo's objective was to eliminate bottlenecks and to reduce the cost of delay. To do so, achieving transparency on current issues resulting in delays was essential. The adoption of scaled agile practices consisting of feature teams with a clearly defined product responsibility and a product backlog with repeated sprints helped to increase transparency on the delivery status and potential bottlenecks.

Adopting an agile structure while following a transparent team structure consisting of feature teams with experienced and broadly skilled employees helped AviationCo to increase transparency on an organizational level. Agile coaches enabled AviationCo's feature team members to adopt agile routines fostering team alignment and identification and, thus, to increase the team's output within each sprint. By this, AviationCo found that short sprint cycles were superior to the traditional (non-agile) approach as a defined workload (i.e., the selected backlog items) is approached within a given period, and in particular, with a clear focus:

> *"We realized that a classical project setting was not helpful for what we were doing and that it is much better to proceed in short, interactive cycles" (Agile Coach, AviationCo).*

Agile practices helped CommunicationCo to properly manage time complexity while considering customer feedback early. Putting the focus on customer priorities and business results by getting things ‘almost ready’ is no feasible option when taking agile practices seriously. Interestingly, AviationCo realized that an agile approach is not faster per se and that the traditional approach is sometimes even faster since it requires less time for alignment and communication:

> *"You only get faster feedback allowing to focus on features with value to the customer but the implementation itself does not get faster due to an increased communication and alignment effort in an agile approach" (Agile Coach, AviationCo).*

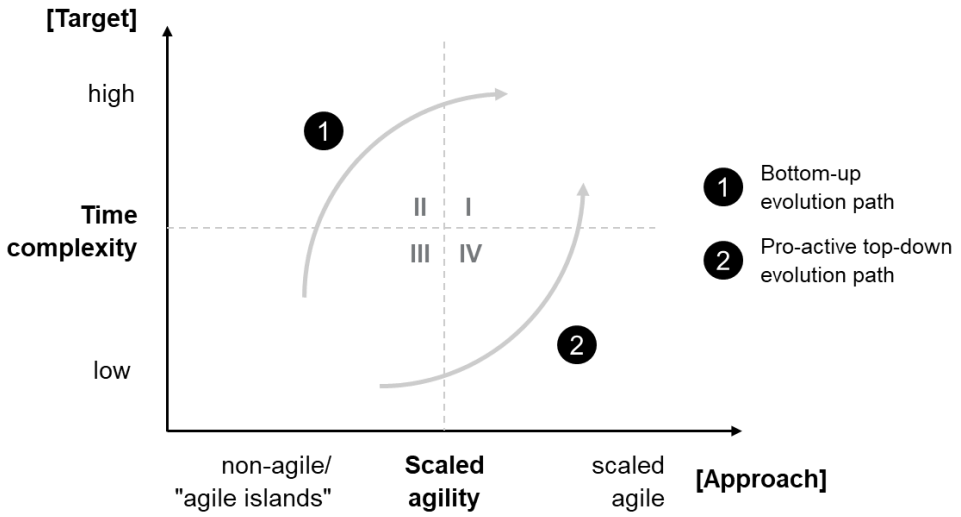
To sum up, all cases purposefully used scaled agile practices and structures to manage their time complex business and activities by successfully addressing different time conceptions and time interdependency challenges while acknowledging and building on temporal management styles.

RECOMMENDATIONS FOR MANAGING TIME COMPLEXITY

The rich and diverse facets of time complexity have been examined with the findings of Fujitsu and four comparative cases of Fortune 500 companies. To manage situations of high time complexity, we derive managerial recommendations for how to keep the different dimensions of time complexity in sync. Based on the measures identified at the individual case study companies, this section summarizes the findings across all cases and reveals two different evolutionary paths for adoption.

Our findings suggest that there are two different approaches for how established companies can manage time complexity: The first approach can be referred to as a bottom-up approach for adopting scaled agile practices retro-actively in cases of initially low complexity or selectively applicable cases of high time complexity – a path that our Fujitsu case undertook. The second approach can be referred to as a top-down approach for adopting scaled agile practices in cases of high time complexity – represented by the comparative cases of AviationCo, AutomotiveCo, CommunicationCo, and BankCo. Figure 2 displays both approaches which are discussed subsequently.

Figure 2. Managing Time Complexity using two Evolution Paths.



As observed at Fujitsu and the four Fortune 500 companies, adopting agile practices helps managing time complexity. The approach for adopting agile practices depends on how companies are addressing imminent challenges resulting from time complexity (i.e., bottom-up evolution approach) or how companies are addressing foreseeable but business-critical challenges to be able to manage time complexity in the near future (e.g., new market entrants in case of AutomotiveCo or a shift of market structure due to digital innovation in the case of BankCo) (i.e., pro-active top-down approach).

Depending on the trigger, companies either may apply agile practices selectively (bottom-up approach) or in a scaled and structured manner right from the beginning (top-down approach). Thus, related to Figure 2, companies evolve from quadrant III to II (in case of Fujitsu's world record) and subsequently slowly traversing to I (in case of AviationCo and CommunicationCo) or from quadrant III to IV and subsequently to I (in case of AutomotiveCo and BankCo).

Apply a Bottom-up Approach in Cases of Initial Low Time Complexity

The bottom-up approach refers to situations where companies are exposed to limited/ foreseeable time complexity or to situations of high time complexity that affect just parts of the organization. This is the case with Fujitsu where the unit accepting the challenge to set a Guinness World Record had been confronted with an ambitious timeline and a high time complexity resulting from multiple time concepts. In these situations, the interdependence across products within a unit or across different units is limited, which thus allows a more flexible approach towards time complexity. Consequently, the bottom-up evolution path is not restricted and affected by a finite timeline. Speed is determined by single units and reflects team-specific requirements for adopting agile practices. This approach can be recommended when an increasing number of units grow organically and adopt scaled agile practices following other units based on their positive experience.

For Fujitsu, a selective and partly even intuitive application of agile practices helped in managing time complexity when setting a Guinness World Record. Likewise, the comparative case study companies AviationCo and CommunicationCo were in a similar situation: Time complexity resulting from different time concepts was initially low. While for AviationCo the primary objective was to foster innovation, CommunicationCo was primarily concerned about decreasing the rate of unfinished projects. In both cases, a selective approach focusing on a gradual implementation of scaled agile practices based on initial learnings and voluntary participation of units had been chosen.

The bottom-up approach helped AviationCo and CommunicationCo to identify and eliminate bottlenecks and to, thus, reducing the cost of delay. Introducing cyclical patterns of repeated activities, as it is the case of agile sprints, helped CommunicationCo to identify almost but not entirely finished projects and to focus on getting things accomplished. Similarly, Fujitsu adopted agile practices in a non-scaled manner as ‘agile island’ to manage high time complexity imposed by the endeavor to set a Guinness World Record. Fujitsu adopted key principles of agile practices (e.g., focus on functionalities

rather than processes) to grasp the opportunity of setting a world record. In that endeavor, top management commitment, while appointing time chunks to a small core team consisting of fully dedicated, self-confident and empowered individuals helped in conjunction with a strong and reliable ecosystem of Fujitsu's partners. Thus, Fujitsu applied cyclical patterns for tasks of the activity ‘World Record’ while thoughtfully transforming activities (e.g., increasing the speed) towards the deadline.

While this approach has the advantage of allowing gradual improvements, trial-and-error, and a more flexible adoption of agile practices, it comes with the disadvantage of a more heterogeneous implementation of applied scaled agile practices and a slower rollout to the remaining parts of the organization. Consequently, as time complexity increases, organizations tend to and should turn successively into a more structured, top-down approach referring to implementing agile practices in a more homogeneous and scaled manner. Tendencies towards a more structured and scaled approach could be observed at both, AviationCo and CommunicationCo, as both decided to apply scaled agile practices according to SAFe in the meantime.

Apply a Pro-active Top-down Approach in Cases of Imminent High Time Complexity

The pro-active top-down approach refers to situations where high time pressure affects large parts of the organization and where different dimensions of time concepts initially apply. For AutomotiveCo and BankCo, new market entrants and high market pressure (e.g., FinTech companies) or innovations (e.g., autonomous driving) made it necessary to find ways to increase speed and flexibility to keep a leading market position. Despite its innovative nature and technological excellence, AutomotiveCo is not untroubled by bureaucratic and inefficient processes which also holds true for BankCo. As observed from these cases, different dimensions of time concepts had to be managed simultaneously requiring a more coordinated and centralized approach.

Both companies already successfully demonstrated that they were able to handle situations of low time complexity as they already managed to reduce time-to-market, cost of delay, and the number of unfinished projects. Especially BankCo introduced scaled agile practices selectively more than five years ago allowing them to already gain profound expertise with agile practices and to fix challenges related to low time complexity. AutomotiveCo and BankCo aimed at an organization-/ department-wide implementation of scaled agile practices which was sponsored and supervised by either the CEO

(BankCo) or the department head (AutomotiveCo) and the implementation took place in a top-down approach within a defined, comparably short period of time consisting of several months.

The top-down approach comes with the advantage of a faster and more synchronized and homogeneous implementation allowing for less freedom for individual units. It is suitable for either cases where time complexity is high and a structured and aligned approach right from the beginning will be required or in cases of a higher organizational maturity where already a common understanding of required measures is present and where there is potentially less resistance from individual units towards a more standardized approach. By this, the adoption of scaled agile practices helped AutomotiveCo and BankCo to address the significant and imminent challenges imposed by digital transformation and resulting in high time complexity.

Consequently, in cases of imminent high time pressure, a pro-active top-down path with a broader scope of implementation can be recommended where the implementation ownership is with the department head or even the CEO. A time-boxed approach with a pre-defined time horizon to conclude the adoption of scaled agile frameworks within a given time is a clear benefit in situations of high time complexity. This approach ensures a closer steering of the implementation with stricter governance and faster – top-down – decision making.

CONCLUDING COMMENTS

The question of how to manage time complexity to increase speed and flexibility is essential to virtually any company in high-velocity markets where the existence of a competitive advantage is inherently unpredictable. While for startups or born digital companies, innovation, speed, and flexibility is the main modus operandi, established enterprises struggle with how to respond to uncertainty and rapidly changing market environments in an adequate and timeline way.

This study is motivated by the lack of empirical evidence on how established enterprises manage different aspects of time complexity. Against this backdrop, we examine how Fujitsu, the world's seven-largest IT service provider and being in business since 1935, set the Guinness World Record for the world's largest animated tablet PC mosaic on November 7, 2017. We adopt a temporal lens justify for the multiple complexity dimensions caused by different time conceptions imposed by challenges related to digital transformation. We perceive this temporal lens as especially beneficially as it provides a

different, more comprehensive view on agility beyond the superficial misperception that agility just equals speed. We learned from Fujitsu and the comparative cases of four Fortune 500 companies that companies apply scaled agile practices selectively to manage time complexities. Exemplarily, the shift from a strict application of sprints following a clock time perspective to modifying a sprint's length in case of already completed work or to reflect for specific occurrences can be perceived as a pragmatic approach to handle multiple time complexity challenges simultaneously. By applying agile practices selectively to manage different time dimensions, Fujitsu succeeded in reducing time complexity despite of an ambitious deadline in combination with technical hurdles, innovation, and novelty.

By comparing the findings related to Fujitsu with four established companies, we reveal that managers should apply a bottom-up approach for adopting scaled agile practices in cases of low time complexity, or a pro-active top-down approach for adopting scaled agile practices in case of high time complexity. Agile practices can contribute in keeping different facets of time complexity in sync to, thus, manage time complexity.

APPENDIX

1. Research Approach

The objective of this study was to gain an in-depth understanding of how time complexity can be successfully managed by adopting agile practices. We examined how Fujitsu set the Guinness World Record for the largest animated Tablet PC mosaic by adopting selective agile practices to succeed in a project involving a challenging objective (i.e., a Guinness World Record), technical novelty, and an ambitious timeline and compared these findings with four cases of established companies applying scaled agile frameworks to manage time complexity. Due to the exploratory nature of this study, a qualitative case-study research approach had been chosen[29].

Related to Fujitsu and additionally to the research team, Robert Mayer supported as co-author of this study with access to interview candidates at Fujitsu and relevant internal information such as internal reports, photos, videos taken during the project's course, presentations, minutes, etc. To further

[29] For further details on how to conduct exploratory research with case studies see: Yin, R. K. 2009. *Case Study Research - Design and Methods*. Sage.

calibrate the data, we conducted and tape-recorded in-depth interviews with Fujitsu's project manager and Fujitsu team members.

Various documentations in the form of pictures, correspondence like e-mails, notes and memos on specific incidents were taken to create an extensive dataset as fieldwork journal[30]. The third author, project manager and other team members were interviewed extensively by the first and second author. This was done through open interviews conducted in person[31]. Transcribed and coded interview material with a total duration of 192 minutes, 108 pictures and 9 videos were evaluated in detail. This approach created a rich set of reflections on the project. All interviews were transcribed and analyzed with the computer-aided qualitative data analysis tool Atlas.ti. The data analysis followed a three-stage process of open, axial, and selective coding to get a comprehensive view of Fujitsu's endeavor to set a world record.

For the comparative cases, in total, 13 semi-structured interviews have been conducted lasting from 32 to 60 minutes led in a discovery-oriented way following a semi-structured interview guideline. All interviews were audio-recorded and immediately transcribed to encourage theoretical sampling and the coding procedure, resulting in 130 pages of verbatim transcript. The coding procedure consisted of open, axial and selective coding[32]. The authors checked the transcripts for completeness and analyzed them separately from one another. Where available, memos or notes were used to capture ideas, further questions, or thematic differences. The qualitative data analysis software MaxQDA supported the coding procedure, facilitating comparison of the coding results and memos as well as checking for sufficient inter-coder reliability. Where interpretations between coders diverged, perspectives were discussed iteratively to reach a consensus. This was done to ensure consistency of coding and interpretation.

[30] Further helpful recommendations for qualitative research can be found in: Yin, R. K. 2015. *Qualitative Research from Start to Finish*. Guilford Publications.

[31] For further details on interviewing techniques in qualitative research refer to Myers, M. D., and Newman, M. 2007. "The Qualitative Interview in IS Research: Examining the Craft," *Information and Organization* (17:1), pp. 2-26.

[32] For more details on interview coding, see McCracken, G., The long interview, Sage, Canada, 1988.

2. Overview of Partners and Architecture Involved

Figure 3. Architecture key components and involved partners

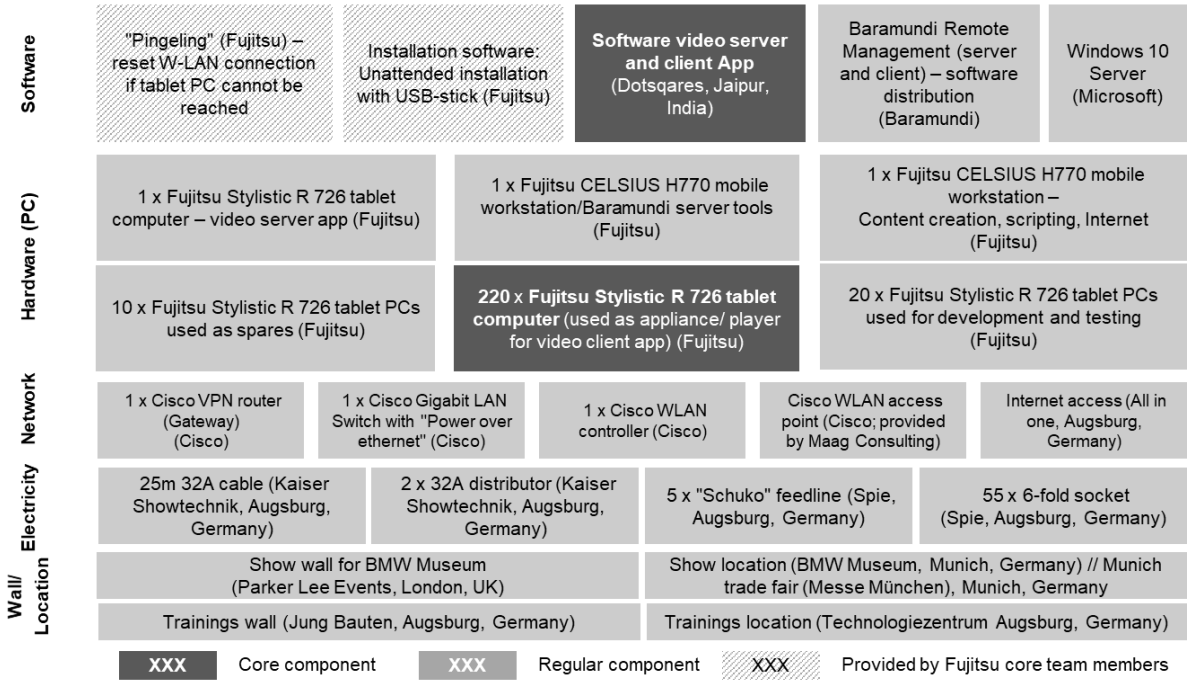


Figure 3 shows the overall architecture and involved partners and is displayed in the chapter entitled 'Fujitsu's way to the Guinness World Record'. The following section provides further information on the involved technical components and partners illustrating the complexity relating to the orchestration of the involved partners and components.

(1) **Hardware**

- 250 Tablet PCs Fujitsu Stylistic R726 including 20 devices for development/testing and 10 spare devices.
- Two mobile workstation Fujitsu CELSIUS H770 used for content creation, scripting, and Internet and for operating Baramundi tools for software distribution to the tablet PCs.
- Cisco wireless access points and WLAN controller, network switches and VPN Routers.

(2) **Software**

- Central server application for the remote control of 220 tablet PCs developed by Dotsqares with the features 'load video', 'start play', 'stop play', 'pause play'. The server app calculates an offset for each tablet PC according to network latency and start all 220 players simultaneously. It can also run a visual overview of the available tablet PCs (like an inventory scan). The player application on the tablet PC is set to a specific location in the grid and displays a video (specific

part of the video content). The player application software with graphic mosaic content is stored locally on the tablet PC (approx. 330 MB).

- Baramundi management suite software used for centralized distribution of software, drivers and scripts to the tablet PCs. Basic controls like reboot, shutdown, applications start and stopping.
- Tool ‘Pingeling’ (developed by Fujitsu) for validating connectivity of tablet PCs and a software for the unattended installation of specific configurations of Microsoft Windows 10.

(3) **Infrastructure**

- Wall (grid A-K vertical and 1-20 horizontal) for installation of the tablet PCs:
    - Trainings wall for the installation of the tablet PCs including electricity supply with each tablet PC having a dedicated wall position.
    - Show-wall for BMW Museum used for the display of the tablet PCs during the VIP dinner event – no electricity supply as tablet PCs are operated on battery.
- Wireless network and routers to connect 223 devices (tablets, server, workstations).
- Electricity supply and distribution of 15 kW (for charging the tablets during development and running on battery during performance).