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# The effects of schedule-driven project management in multi-project environments

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**Abstract**

Prior work has affirmed the importance of studying project management in multi-project environments. A challenge in these settings pertains to the need to share skilled resources across concurrent projects when project management is schedule-driven and resource capacity is fully committed. To probe into this problem, we use a system dynamics simulation grounded on in-depth fieldwork with a high-performance truck developer. We simulate the effects of capturing resources allocated originally to one project so as to speed up another product development project that started late. Our central contribution is to illuminate how a schedule-driven project management policy can lead to a vicious cycle that degrades the organization's capability to meet the planned project milestones in the long-term. Whilst capturing resources can ensure that a tardy but 'business-critical' project is delivered on time, if the organization has no free resource capacity and is also not recruiting more staff, this practice harms the schedule performance of the projects deprived from resources. Further, the workforce's productivity gradually deteriorates as the frequency with which staff switches back and forth between projects increases. These effects compounded cause delays in all the subsequent projects, irremediably degrading the organization's capability to deliver projects on time reliably.


*Keywords:* Multi-project organizations; Schedule-driven management; Product development projects; Resource allocation; System dynamics

## 1. Introduction

How do product development and manufacturing firms survive in competitive markets? To survive, seminal studies show that these firms have to keep continuously making incremental improvements to existing products and developing new products that incorporate emergent technologies (Wheelwright and Clark, 1992). New product development therefore typically unfolds in a multi-project environment wherein different teams have to share some skilled and scarce engineering and design resources (Laslo and Goldberg, 2008; Geraldi, 2008; Canonico and Söderlund, 2010). In competitive markets, manufacturers also tend to operate under pressure to accelerate product development and reduce time to market so as to meet the customers' evolving needs and demand for cutting-edge technologies (Lieberman and Montgomery, 1988; Calantone and Benedetto, 2000; Ward et al., 1995). In this study, we define schedule pressure as the tension caused by the gap between the project manager's perception of the work days necessary to complete the project with the resources originally allocated to the team and the actual work days left before the planned completion date. Schedule pressure is low if the project appears to be on time and the work left is unlikely to require the team to work long hours. But it is high if the project team perceives planned milestones will be missed unless the project is de-scoped or staff put long hours, even assuming that no unexpected 'fires' (Repenning, 2001) emerge in the late stages. Existing studies suggest that projects unfolding in multi-project environments under schedule pressure are frequently delayed, a phenomenon which tends to negatively impact on the firm's overall business performance (Griffin, 1997; Blichfeldt and Eskerod, 2008).

A fundamental insight that emerges from studies of multi-project organizations is that specialized resources switch

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frequently between projects in these settings, and this is a root cause of schedule pressure (Geraldi, 2008; Kaulio, 2008; Laslo and Goldberg, 2008; Jonas, 2010; Canonico and Söderlund, 2010). In particular, top management may find it attractive to capture resources from other concurrent projects so as to accelerate a business-critical project that started late if the organization has no free capacity in terms of specialized resources and is not hiring new staff, or the organization is finding it difficult to recruit new staff with adequate skills (Yaghootkar, 2010). In the short-term, the bold practice of capturing resources from a concurrent project can be effective to ensure that the project deemed 'more important' finishes on time. However, increasing the size of a project team to attempt to speed up project delivery is notorious for decreasing productivity (Brooks, 1995). Work productivity also deteriorates because learning curves get disrupted as resources switch back and forth between projects (Abdel-Hamid, 1988). These insights leave open, however, the central issue addressed here. Specifically, we ask: 'which are the long-term effects of schedule-driven project management sustained by a resource capturing practice in a multi-project organization when there is no free resource capacity?'

Our research design is a longitudinal, experiential simulation of a multi-project organization in which a resource capturing practice is used to implement a schedule-driven project management policy. Our computer-simulated environment is grounded on in-depth fieldwork with the product development organization of a manufacturer for high-performance trucks. We assume that, first, there is no free resource capacity; second, skilled staff are not being recruited; and third, productivity declines when resources switch back and forth between concurrent projects. Our simulation includes various scenarios that increase deliberately the initial delay in starting a project deemed 'business-critical'. Due to the schedule-driven project management policy, these delays increase the frequency with which resources switch between concurrent projects.

Our central contribution is to illuminate the short-term logic and long-term detrimental effects of decisions to capture resources allocated to other concurrent projects. In the short-term, this policy ensures that a tardy project can be delivered on time. This can be business-critical, for example, when the business faces the prospect of significant loss of anticipated revenues if the project output fails to reach the market before a pre-determined calendar date or before a competitor reaches the market with a similar product. Ensuring that some projects finish on time can also be business-critical if a contract with a third-party imposes significant penalties for delays. In the long-term, we show that a resource capturing practice in an environment without free capacity puts the concurrent projects under schedule pressure in a ripple effect. Assuming productivity deteriorates as resources move across projects routinely in agreement with existing studies, we show that schedule-driven management with resource capturing exacerbates schedule pressure in a self-reinforcing vicious cycle, generating a persistent steady state that degrades the organization's capability to deliver projects on time reliably.

## 2. Background: complexity of managing multi-project environments

The understanding that the single-project paradigm is so ingrained in scholarly literature to the extent scholars may fail to acknowledge it as a simplifying assumption has long stoked calls for more studies on multi-project environments (Elonen and Artto, 2003; Fricke and Shenhar, 2000; Engwall and Jerbrant, 2003; Söderlund, 2004; Canonico and Söderlund, 2010; Aritua et al., 2009). In these settings, concurrent projects are often intertwined due to interdependencies between inputs and outputs and sharing of specialized resources (Fricke and Shenhar, 2000; Kaulio, 2008). From a project management perspective, these environments can be challenging – when not chaotic (Geraldi, 2008) – since disruptions in one project due to an unexpected event can ripple through the performance of concurrent projects (Pavlak, 2004). Aware of this, Nobeoka and Cusumano's (1995) seminal work argues that both project- and function-based organizations perform poorly in managing multi-project organizations, and recommend that firms set up matrix-based structures to guarantee that project and functional managers negotiate effectively project priorities and resource allocations. Still, the authors recognize that this is easier said than done, especially if many concurrent projects stretch the organization's resource capacity to arguably unreasonable limits. This forces the overcommitted teams to compete fiercely for staff, and some projects end up running late (Kuprenas, 2003; Dooley et al., 2005; Laslo and Goldberg, 2008).

Interestingly, from an operations research (OR) perspective, the problem of managing multi-project organizations is well explored. And significant advances have been accomplished that put forward appropriate algorithms for scheduling, resource leveling, and aggregate resource planning, e.g., Kurtulus and Davis (1982), Tsubakitani and Deckro (1990), and Wiley et al. (1998). But the management of multi-project organizations remains challenging since these methods are underpinned on a rationalistic decision-making paradigm, a logic which can be at odds with the politically loaded negotiations driving project decisions (Pennypacker and Dye, 2002) and influential 'soft' variables in multi-project environments including leadership (Kaulio, 2008), project manager's empowerment (Jonas, 2010), and incentive alignment (Laslo and Goldberg, 2008). OR methods also appear ill-suited to address the challenges of managing multi-project organizations under uncertainty and to model managerial practices suitable to these environments. For example, Eisenhardt and Tabrizi (1995) describe an experiential strategy to reduce development time under uncertainty which relies on the teams' ability to improvise, iterate, prototype, utilize their own experiences in real time, and empower the project leader — practices hardly addressed in conventional OR literature.

Another notion central to the management of multi-project product development environments is project speed. To survive in competitive environments, project staff are often required to operate under challenging timescales and undertake many projects concurrently (Rosenau, 1988; Crawford, 1992; Canonico and Söderlund, 2010; Geraldi, 2008). High levels of schedule pressure require that project teams work long hours, which can cause staff to experience stress and health problems over time that harm productivity (Karasek and Theorell, 1990). Overcommitted teams are also more prone to make errors that need to be reworked, further delaying the project (Abdel-Hamid, 1988).

To preclude projects from running late in a multi-project setting, managers often resort to fire fighting — a reactive process associated to the quick allocation of scarce resources to solve unanticipated problems or 'fires' discovered late in the product development's cycle (Repenning, 2001). Repenning's study shows that multi-project organizations can get trapped in a persistent firefighting mode whenever teams fail to spend enough time up front agreeing critical parameters, discussing uncertainties, and devising risk mitigation strategies. The persistence of fire-fighting is detrimental to the organization's performance as it can lead to fatigue, burnout, turnover, and increased chances of further errors (Repenning, 2001). Repenning's simulation experiments identify a tipping point, i.e., a threshold of resource allocation to project frontloading, which organizations need to attain so as to prevent fire fighting from becoming a steady state. Critically, fire fighting can become a self-reinforcing phenomenon when teams are kept overloaded.

Repenning's (2001) work is the closest to this study. But our focus is different. Schedule pressure here is not a consequence of emergent late problems due to poor front-loading, but a consequence of a schedule-driven project management policy to finish projects deemed business-critical on the planned completion date even if they started late and there is no free resource capacity. We attribute late starts to conflict among project and senior management, a typical issue in multi-project organizations (Laslo and Goldberg, 2008; Jonas, 2010). After presenting our empirical setting and the system dynamics simulation grounded in this setting, we analyze and discuss the simulation results.

## 3. Research design and setting

Our research design involves experiments using a system dynamics simulation model grounded on in-depth fieldwork with a multi-project development organization for high-performance trucks. System dynamics is a modeling paradigm suitable to visualize and assess how the structure of a complex system generates its behavior, particularly through the simulation of closed-loop systems, i.e., systems which future behavior is affected by the results from past action (Sterman, 2000). Feedback loops are the unit of analysis for causes of behavior in system dynamics. These loops express causal relationships between the critical variables in the system. Loops can be positive or reinforcing ('R') when they move the system in the same direction as the initial change; or they can be negative or balancing ('B') when they move the system towards some desired target by creating action, eventually after a delay, in the opposite direction from the discrepancy between the actual and the desired target values. The system dynamics approach posits that loops are responsible for the modes of behavior (exponential growth, oscillation, and amplification) that the system may exhibit over time (Sterman, 2000 p. 28). To study the behavior of complex systems, system dynamics advocates factoring "soft" variables, e.g., exhaustion, frustration, wishful thinking, and strategic misrepresentation in mapping causal relationships (Sterman, 1994; Ford and Sterman, 2003). These behavioral notions are hard to measure, but they can be parameterised and their effects explored through sensitivity analyses and experiments (Lyneis et al., 2001).

The first step to build our system dynamics model was to represent the structure of our focal multi-project organization in a causal map. These maps, also called influence diagrams, express the structure of the system in terms of variables and causal relationships between variables (Forrester, 1968). A relationship with a (+) polarity means that a change in the emanating variable causes a change in the same direction in the variable at the end, and a (−) polarity expresses the opposite effect. The setting up of boundaries for the causal maps was informed by the research purpose (Forrester, 1961 p. 114). To advance our understanding of how multi-project organizations behave under different conditions of schedule pressure, or as put by Sterman (2000 p. 95) to develop an endogenous explanation for complex dynamic behaviors, we converted the causal maps into a simulation model. We then conducted experiments to explore how multi-project organizational performance gets affected when a project that starts late captures resources from a concurrent project. Assuming there is no free capacity, we gradually increased the delay in starting the project deemed 'business-critical' to simulate varying conditions of schedule pressure. We next describe the relevant features of our setting.

### 3.1. Research setting

Our empirical setting was the product development division of Alpha, a manufacturer of high-performance heavy goods vehicles ('trucks'), where one of the authors did various work placements. A director of Alpha's product development division was our key informant. This setting is germane but underexplored in management research. Whereas cars are consumer products by and large, and purchasing decisions are influenced by personal taste, price, esthetics, and styling, truck customers are predominantly short- and long-haul trucking companies, and not the truck drivers. In their purchasing decisions, trucking companies pay particular attention to long-term reliability, durability, and serviceability, mindful that one truck alone can cost over $150,000 (Thomas, 2002).

For truck manufacturers, to keep trucking companies loyal to the brand is paramount since manufacturers know it is difficult to bring back a customer once it switches to a competitor at the time of renewing the truck fleet. To preserve customer loyalty, manufacturers need to respond nimbly to ongoing evolution in relevant technologies (e.g., vehicle tracking,[1] fuel efficiency, and emission reduction) and in regulation (e.g., ports of Los Angeles and Long Beach have recently banned pre-1994 trucks to force companies to buy cleaner trucks), as well as to after-

[1] Technology that uses a vehicle location unit and mobile telecommunications to track truck positions.

market problems and competitors' new products. As a result, concurrently with projects to develop new truck platforms, truck manufacturers are continuously developing new variants out of existing platforms. The design life of a truck platform may last up to 30 years, during which period hundreds of variants may be generated through so-called 'incremental' or 'maintenance' projects. This inexorably makes new truck development a multi-project environment.

The case of Alpha is telling. Alpha builds about 100,000 trucks – mostly tractor units for semitrailers or rigs – each year. But the vehicles that Alpha produces are not simple, commodity items. Rather, within its annual production total, perhaps as few as two vehicles might be exactly identical such is the range of variants and configuration options available to customers. Alpha's strategy is to give customers a wide range of configuration options, almost building trucks to customers' specifications, without compromising standards or increasing support costs. Following a 'strategic bucket' approach (Cooper et al., 1997), a top management committee is in charge of chunking and allocating the annual budget to the different project proposals submitted by the product development teams jointly with marketing and sales. The approved projects will then share the same pool of specialized resources as one respondent explained (2009):

> "The interdependences between multiple projects have become important for us. Maybe 10 years ago, projects had dedicated resources and not much coordination was required amongst projects. Today, we've many more projects, many of them are just very small ones to improve a component or fix a problem in the product. We've common technologies in multiple products and all these create an environment wherein we, knowingly or unknowingly, affect each other's projects"

### 3.2. Data collection

Data collection included over eighty one-on-one interviews, eight group presentations, a 4-hour workshop with 8 participants, analysis of archival documents, and direct observations at Alpha over five years elapsed time (2004–2009). Direct observation and analysis of archives helped to understand the processes and organization of Alpha's multi-project environment, whereas the semi-structured interviews revealed respondents' views on the main variables and causal relationships affecting project performance. The respondents had job roles as diverse as engineering designers, project and functional managers, and portfolio managers. The first stage of the fieldwork was a 5-month student placement during which the first author participated in some quality improvement projects. During this period, we became aware of the critical notions of schedule pressure and resource scarcity affecting the organization's project performance.

The second stage of the fieldwork focused on collecting data necessary to develop the causal maps. To this purpose, our key informant put together a list of potential respondents and an electronic note sanctioning the data collection process. This stage included over 50 one-on-one interviews that lasted 1 h on average. A snowball tactic (Biernacki and Waldorf, 1981) was used to collect data, thereby asking respondents to identify colleagues who could supplement data on the emerging causal relationships. As part of the interview protocol, we developed a questionnaire (Appendix I), recorded the interviews in audio files, and transcribed the interviews into word documents. Iteratively, we developed a comprehensive map that consolidated our understanding of the endogenous feedback loops affecting the multi-project organization's performance (Yaghootkar, 2010). We then implemented a subset of this map into a simulation engine to probe into the effects of one critical managerial policy: top management's insistence that particular projects deemed business-critical finish on the planned completion date, or as nearly as possible, even if budget negotiations delayed the project start and the organization's resources are fully committed. To validate the insights of the simulation experiments, we conducted a half-day workshop. We next explain how we consolidated our empirical understanding into a computer-based simulation model.

## 4. Simulation model development

### 4.1. Causal mapping

Our data suggest that in a multi-project environment with no free resource capacity nor with capacity increases in prospect, project performance is affected by interdependencies with other concurrent projects as well as by knock-on effects from prior projects. It is the responsibility of top management to oversee the interdependences between projects and longitudinal knock-on effects. Fig. 1 depicts the corresponding feedback loops.

The fieldwork identified three fundamental feedback loops at the core of the schedule pressure phenomenon. At Alpha, skilled designers and engineers have some degree of freedom to allocate their time across the different projects in which they work simultaneously. Staff appreciates this flexibility whilst aware that top management has authority to instruct them to shift their attention to particular projects that may be running

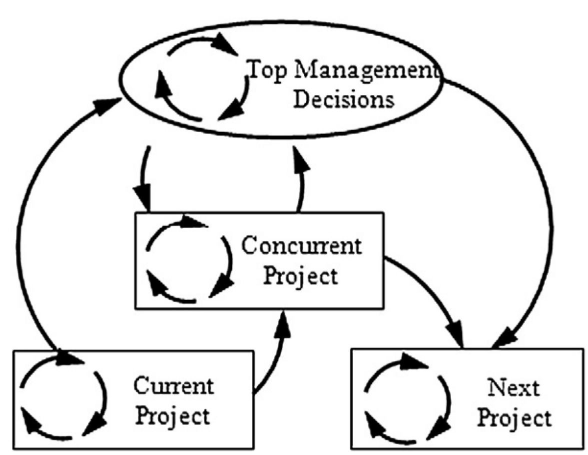


Fig. 1. Intra- and inter-project dynamics and top management decisions.

late and are deemed business-critical. Thus top management views engineering staff as inherently flexible to cope efficiently with moves across projects. But staff argues that this practice affects their productivity. One workshop participant observed:

> "It seems OK to move resources between projects, but we should be rational on this. It would be OK to keep moving people between projects if they were like boxes. But we aren't boxes. Reallocating people costs money for training and administration, and reduces productivity"

Extant theory corroborates this finding: extreme levels of multitasking and resource re-allocation between activities penalizes productivity due to increases in set up and coordination costs (Rosen, 2008); full-timers also tend to perform better than part-timers because the latter have to spend more time on non-value-added tasks such as remembering and tracking down information (Wheelwright and Clark, 1992 p. 90; Cusumano and Nobeoka, 1998 p. 25). Still, our data suggest Alpha top managers systematically introduce too many projects, thinly spreading staff across different projects and moving people between project teams whenever they find it appropriate:

> "When you're working on a project which is going according to the plan, it's likely that you may be called to join a team which has resource problems and is running out of time …those projects in trouble pull the resources in whatever means they can, usually overriding previously agreed plans" (Engineer, Spring 2007)

In our causal map (Fig. 2), the variable *Taking Resources away from Concurrent Project* refers to capturing resources from one project to allocate them to a concurrent project deemed more 'important' and that is running late. As a result, the concurrent project deprived from resources can face schedule pressure problems in the future. This problem is compounded because productivity declines as resources move between projects. These relationships are expressed through the balancing loop B1 and the reinforcing loops R1 and R2. For the sake of expressiveness, the map only represents two projects, but it could be expanded to represent many projects. Specifically, the variable *Schedule Pressure on Current Project* causes *Taking Resources away from Concurrent Project*; this reduces schedule pressure on the current project completing the balancing loop. But as the concurrent project loses resources after an un-capacitated delay (i.e., resources don't change during the delay), *Schedule Pressure on Concurrent Project* increases. This project can thus also be affected by schedule pressure, requiring other projects' resources later on. This relationship completes the reinforcing loop R1.

The re-allocation of resources between projects reduces productivity. This effect surfaced repeatedly in the fieldwork. The reinforcing loop R2 expresses this: *Taking Resources away from Concurrent Project* increases *Setup Time*, which reduces *Productivity*. Low *Productivity* reinforces *Schedule Pressure in Current Project*.

### 4.2. Simulation

To experiment with different schedule pressure conditions after implementing the causal map in a simulation engine, it required defining a main independent variable. Here, this variable expresses the extent top management instructs project teams to operate under schedule pressure by insisting that a project finishes on time, or as near the deadline as possible, irrespectively of any delays affecting its start. Our data support this logic:

> It's a good assumption that the project deadline is unchangeable. That is the situation here. We often cannot change the

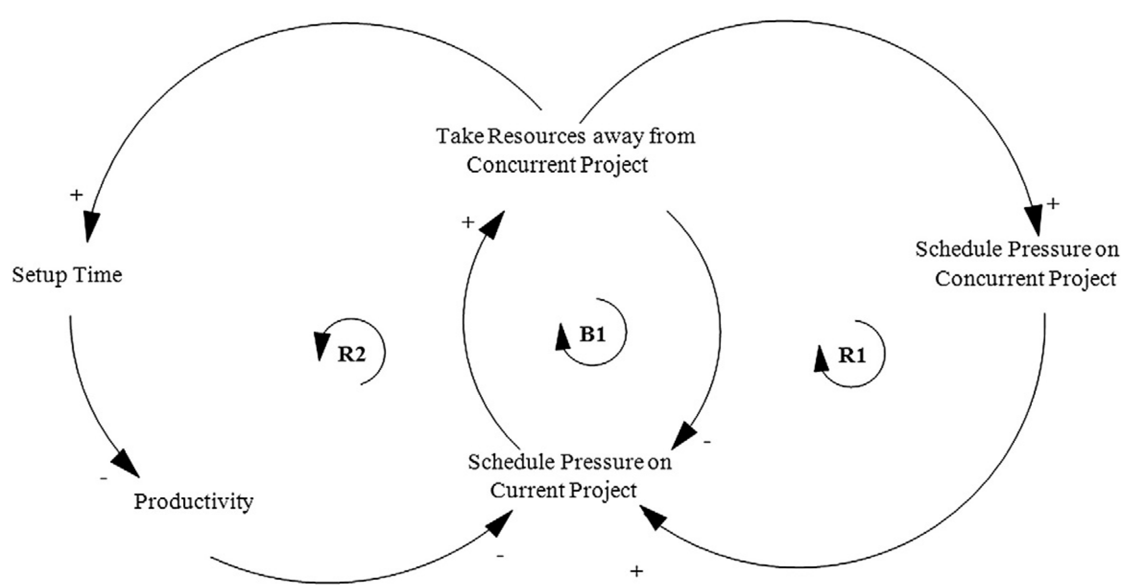


Fig. 2. Causal map with three feedback loops.

start of production and the order in-take date by the customer since some are must-do projects that the brands want as soon as possible; but the start of the project itself is delayed very often (Portfolio Manager, Summer 2006)

Indeed, respondents mentioned systematically that delays in the project start are common since a project cannot start until middle and senior management agree the budget. In agreement with other studies (Laslo and Goldberg, 2008), our data indicate negotiations can be protracted if senior management perceive that the middle managers' budget is too conservative. Although the project will then start late, project teams may agree to leave unchanged its deadline so as to avoid further internal conflicts and delays:

> We spend a lot of time discussing the project budget and scope, and it seems this process isn't productive as it should be. We end up keeping the projects in pending state for a long time, agreeing estimates hastily, and starting the projects when the time left is short. In fact, I think it's time which makes the decisions for us (Project Manager, Summer 2006)

An assumption underpinning the simulation is that the organization operates with no free resource capacity. The fieldwork suggested this is a reasonable assumption considering that project teams are formed mainly by highly skilled engineers that are a scarce resource. Even when schedule pressure is extreme and teams flag the urgency to hire more staff, senior management may be reluctant to do so; recruiting workers with the adequate skills can also be a protracted process. As a result, top management will overcommit staff, and ask them to work overtime to respond to an increased workload:

> "I'm involved in too many projects. But when a project gets into trouble, we have to accept new assignments. The problem is when two or more projects get under pressure. Every project manager wants me to work on and prioritize his/her project. It's impossible! We always do some work overtime but sometimes we work over overtime" (Engineer, Spring 2007)

Our main dependent variables to assess performance are project progress, project duration, and resource switches between projects. To simulate a multi-project environment, we force four projects that have similar resource needs to overlap to some degree (Fig. 3). This conceptualization was implemented with Powersim Studio 2005, a commercial development environment suitable to create system dynamics models, and perform simulation runs and analysis. Powersim transforms graphical representations of causal maps into a simulation model, thereby defining mathematically the variables and the relationships between variables. Powersim also verifies model logic by checking the relationships between variables for any inconsistencies in units. To perform sensitivity analyses, we implemented two mechanisms, project progress and project prioritization, and used Powersim's presentation controls to change input data.

### 4.3. Project progress mechanism

The project progress mechanism (Fig. 4) determines the project progress rates over the simulation time, and keeps track of how much project scope is being delivered.

Each project consists of a number of work packages. Fig. 4 represents the project progress mechanism in a stock and flow diagram — stocks are denoted by rectangles and represent accumulation of work packages, whereas flows are denoted by arrows with 'valve' symbols and represent action within the system. The work packages are initially stored in a 'stock' variable: *Project i*

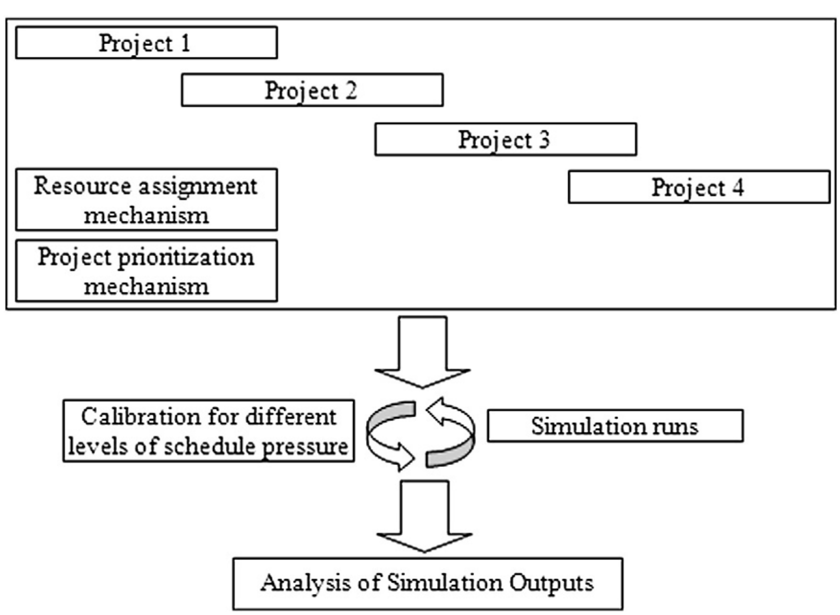


Fig. 3. Simulation of a multi-project development environment.

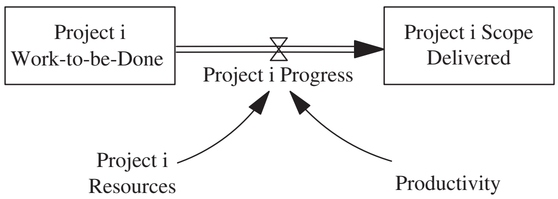


Fig. 4. Project progress mechanism for project *i*.

*work-to-be-done*. During the simulation, work packages flow through flow-variable *Project i Progress rate* to stock *Project i Scope Delivered* (see Appendix II for mathematical modeling details). This structure draws on prior system dynamic simulations of projects (Roberts, 1974; Abdel-Hamid and Madnick, 1991). Also drawing on these studies, we use an S-shaped natural logarithm to model project progress. This assumes that the project initially progresses slowly while ambiguities are eliminated, it reaches a maximum rate mid-course, and it slows down again once it nears completion to account for time-consuming testing and verification activities (Miskawi, 1989). Following Pidd's (2003) work, we asked respondents to draw resource allocation curves for an average project so as to calibrate numerically these variables (Fig. 5). In the Appendix II, we illustrate the control dashboard used for experimenting different conditions of schedule pressure in the simulation runs.

### 4.4. Project prioritization mechanism

The fieldwork revealed that the key heuristic used by top management to prioritize a project relative to others for resource allocation purposes relates to the extent a business-critical project is likely to overrun the original deadline. This is equivalent to assessing priorities based upon the estimated damages from a hypothetical delay, a heuristic unearthed in Kavadias and Loch's (2003) study. Once a project becomes a priority, its team is instructed to capture resources from concurrent projects so as to bridge the gap between the actual team size and the resource target likely to ensure that the project can be finished on time without over committing staff. The fieldwork also suggested that a sense of urgency affects decisions to prioritize particular projects: delays relative to the planned progress may go unnoticed in the early stages, but project attention increases dramatically as the deadline gets closer. To model project priority, we again followed Pidd's (2003) methodology and asked respondents to graph their perceptions. The maps indicated an exponentially shaped behavior. Thus, the urgency to capture resources from other projects is relatively low in the early stages, but it escalates exponentially as the project unfolds if the prospect of a major delay is anticipated unless action is taken. The resource allocation mechanism (mathematically represented in Appendix II) factors in a delay between a project becoming a priority relative to other concurrent projects and receiving additional resources. This delay accounts for the need to let staff close off tasks in the previous project before moving de facto to the new project (Fig. 6).

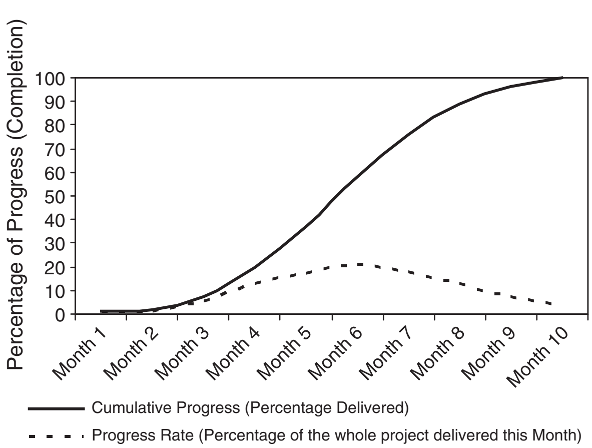


Fig. 5. Cumulative project progress and progress rate.

## 5. Results and analysis

To reproduce a multi-project development environment, we simulated four projects starting in a tight sequence. We then gradually increased the delay on starting the first project without changing its target deadline nor changing the planned starting dates for the subsequent projects. This perturbation of the system creates scenarios of increasing schedule pressure on the first project which quickly becomes a priority relative to the other projects for purposes of resource allocation. We used empirical data about an average incremental project at Alpha to calibrate numerically the experiments. Hence each simulated project comprises 200 equal-size work packages, and the gap between the start of two subsequent projects was set in 100 d. Technically, the step time of the simulation was set at 0.125 d to guarantee an acceptable integration error; lower values would increase significantly the duration of the simulation runs with a marginal benefit in accuracy. The simulation runs last one year and a half in simulated time so as to let all the projects finish even when the first project starts extremely late.

As noted, when the start of project 1 is delayed, this project captures some of the resources allocated originally to project 2 — the project scheduled to unfold concurrently with project 1 after a time lag. Likewise, in a later stage of the simulation, project 2 captures resources from project 3. As a result, a delay in the start of project 1 will increase the elapsed time needed to deliver the subsequent projects that get deprived from the resources originally allocated to them. This dynamic behavior assumes that the organization operates without any free resource capacity, and accordingly, to accelerate one particular project, top management has no alternative but to capture resources from projects that were scheduled to unfold simultaneously. In the simulation, the only project that unfolds concurrently with project 1 when the resource-capture decision is made is project 2, which then loses resources. Fig. 7 illustrates the effects of schedule pressure on the project progress rates and on the cumulative project progress when the start of the project 1 is delayed by 70 (dotted line) and 110 d (solid line).

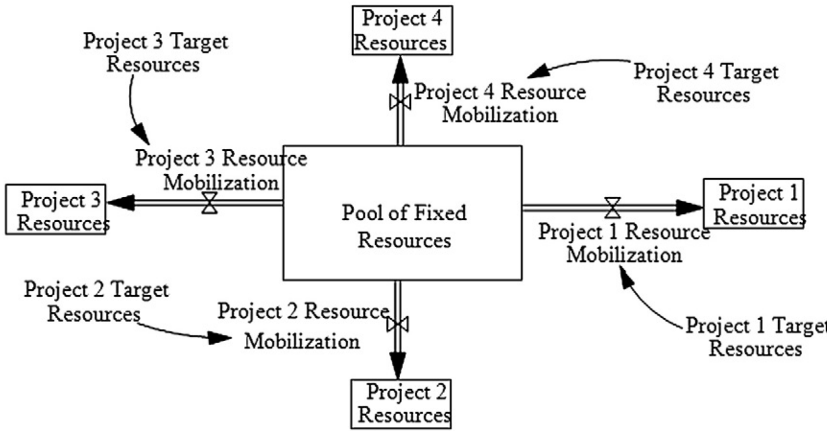


Fig. 6. Resource allocation based on project prioritization.

The simulation experiments show how the delay in the start of project 1 harms the schedule performances of all the subsequent projects. This effect can be better understood by analyzing the oscillation in the size of the project teams in Fig. 8.

When the start of project 1 is delayed, this project becomes a priority and captures additional resources during the early stages. As project 1 nears completion, its priority status changes and it starts releasing resources. In the meantime, because project 2 lost resources mid-course to project 1, it has

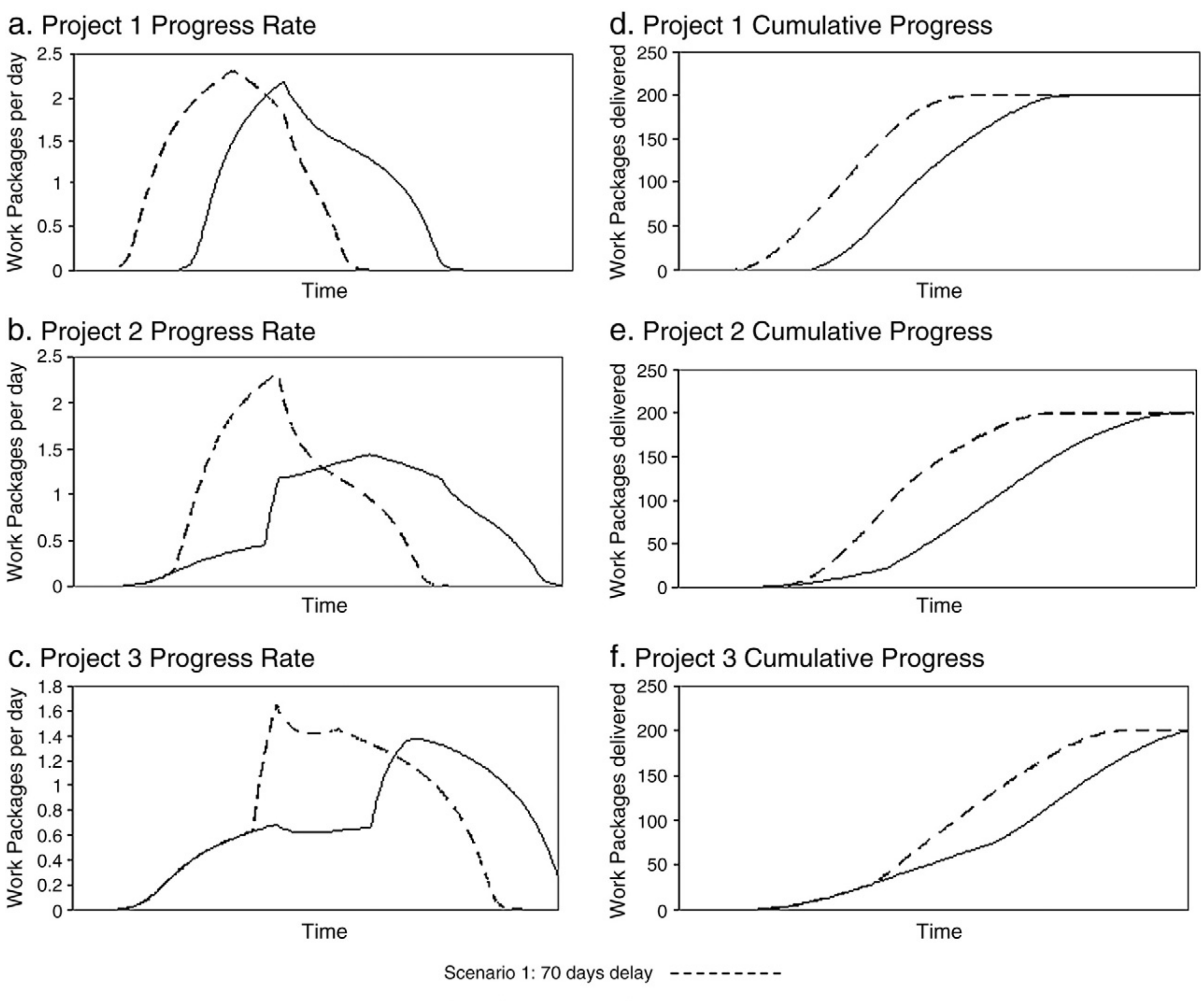


Fig. 7. Results of the simulation experiments for delay in project 1 start.

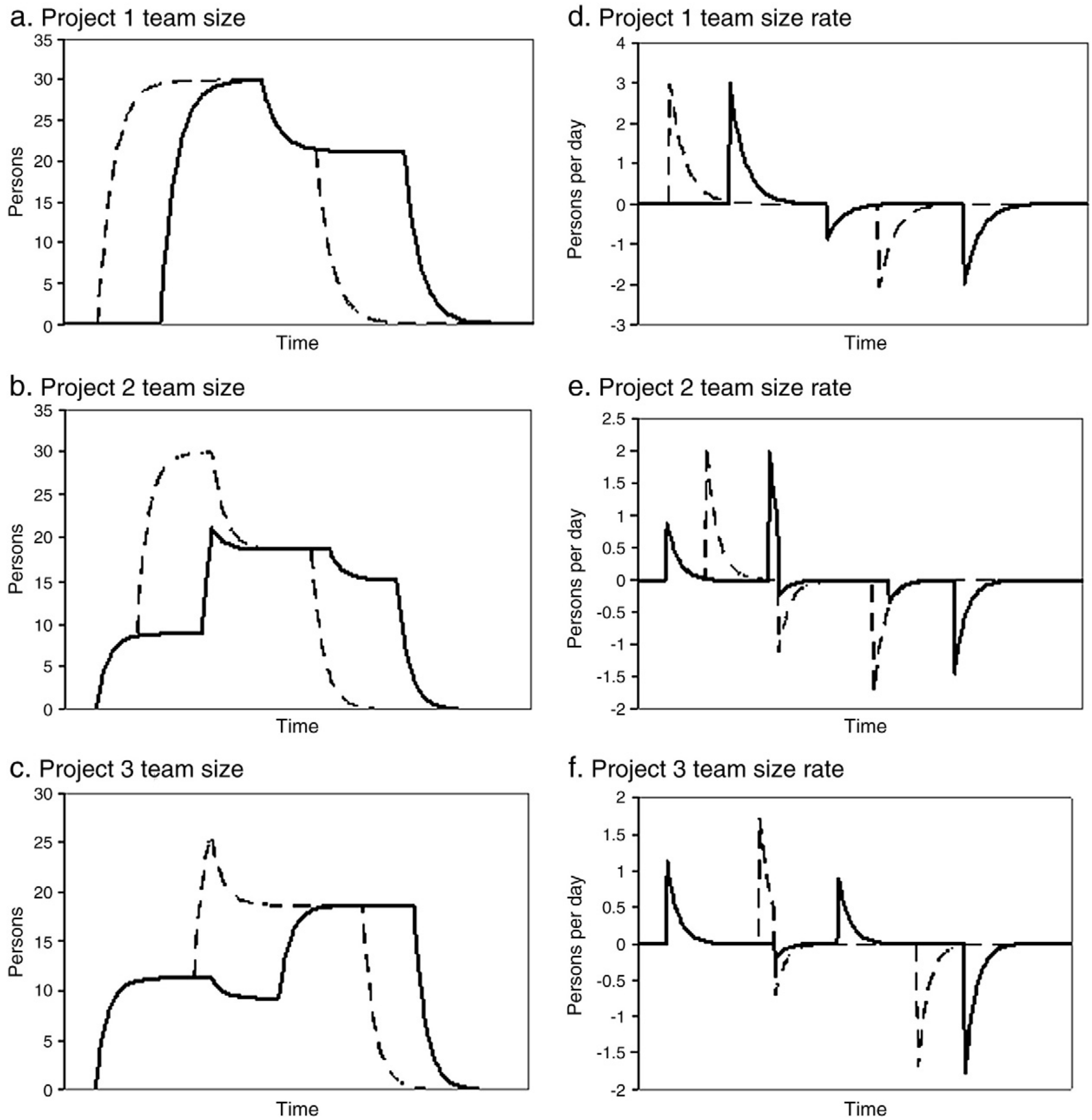


Fig. 8. Oscillation in size of project teams for delay in the start of project 1.

become a priority relative to the other concurrent project (project 3 in the simulation), and it will also capture some resources from that project; likewise, project 3 receives additional resources at a later stage once the priority status of project 2 changes again. Interestingly, the frequency of the oscillation in the teams' sizes intensifies over time. Hence, project 1 captures resources in one period to release them later in two periods; project 2 captures resources in two periods to release them later in three periods; and project 3 even releases resources between periods during which it captures resources because of intense fluctuation of its relative priority — a pattern harmful to productivity but in agreement with the fieldwork.

In Fig. 9, we compare schedule performance when the start of project 1 is gradually delayed from 0 up to 150 d. The results

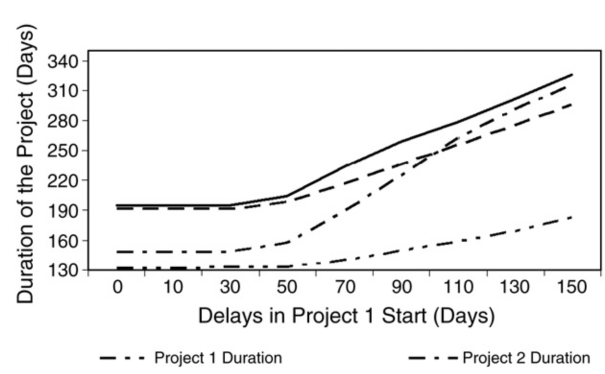


Fig. 9. Project durations as a function of a delay in the start of project 1.

are interesting. As expected, project 1 is the least affected by the delay in its start since it keeps its high priority status for resource allocation purposes relative to the other projects due to its closest deadline. In contrast, project 2 is the most affected by the delay affecting the start of project 1. Not surprisingly, a marginal delay in starting project 1 hardly affects the schedule performance of the other projects. But as the delay in starting project 1 increases beyond the 30 d threshold (already significant considering that the original planned duration for project 1 is 132 d), the elapsed durations of all the subsequent projects start to increase sharply due to lower productivity in a knock-on systemic effect.

In computer-based simulation, modeling extreme even if unrealistic scenarios is a useful practice to uncover hidden assumptions and test the robustness of the model's logic (Sterman, 2000). In our work, at the extreme scenario where project 1 starts 130 d late, i.e., it starts when it should be finishing, the elapsed durations of the subsequent projects (2, 3, and 4) increase dramatically. Interestingly, in this extreme scenario, even project 1 takes more days to complete relative to its original planned duration. This indicates that in our model, an extreme delay in starting a business-critical project triggers a dramatic increase in the team size that produces a sharp decline in productivity (Fig. 10). Whilst studies show a limit beyond which adding more staff harms work productivity (Abdel-Hamid and Madnick, 1991; Brooks, 1995), we would expect responses to extreme delays to produce more reasonable behaviors in the real-world. We discuss this and other opportunities to improve our model in the last section.

Overall, the simulation experiments show that a schedule-driven project management policy in an environment operating without free resource capacity can have long-term detrimental impact to the multi-project organization's capability to meet planned project milestones. This result is at the core of the value of using system dynamics, a paradigm useful to assess the long-term consequences of complex interactions among variables and the effects of managerial decisions. We discuss next these insights.

## 6. Discussion

Our study reveals how a schedule-driven project management policy sustained on capturing resources from concurrent projects can harm the long-term multi-project organization's capability to meet planned project milestones. This insight is grounded in a context in which the organization has no free resource capacity but is nonetheless reluctant to hire new staff, relying instead on the existing workforce to work overtime — a scenario not atypical in jobless economic recoveries (The Economist, 2010). Specifically, the experiments illustrate that as top management puts pressure on a team to complete a particular project on time, the delays in the elapsed durations of subsequent projects added together tend to exponentially increase due to a conflation of factors: first, as one project loses resources, it also becomes under schedule pressure after a time delay; second, as more projects become under schedule pressure, resources switch back and forth more frequently in response to increased oscillation in project priorities; and third, with increased fluctuation in the teams' size, productivity decreases. These effects compounded exacerbate schedule pressure in a self-reinforcing vicious cycle, generating a persistent steady state that degrades the organization's long-term performance in terms of its capability to deliver projects efficiently. This result is consistent with Repenning's (2001) claim that fire-fighting is self-reinforcing. It is also in agreement with prior studies which suggest that the urgency to resolve short-term problems often motivates organizations to overlook the long-term effects of short-term fixes (Repenning, 2001). Interestingly, our fieldwork reveals practitioners are aware that a schedule-driven management policy can harm the long-term organization's capability to deliver projects efficiently. But the empirical findings also suggest that conventional wisdom has been inadequate to talk top management out of deep-seated practice.

These insights add to extant scholarly literature on the structure and behavior of multi-project organizations (Repenning, 2001; Geraldi, 2008; Aritua et al., 2009; Laslo and Goldberg, 2008). Seminal studies have highlighted the negative consequences for a product development firm carrying on more projects than its resources can handle effectively. Metaphorically, Wheelwright and Clark (1992 p. 90) call it the 'Canary Cage problem' — canaries (projects) which are weaker find themselves pushed to the bottom of the cage, dumped on by their fellow canaries, and they become sick and die. It was an open issue in the literature, however, the extent to which this problem results exclusively from resource scarcity, or rather, it should be attributed as well to the application of particular project management policies. Based on an in-depth empirical study and experiential simulation, our central contribution is to show how schedule-driven project management when there is

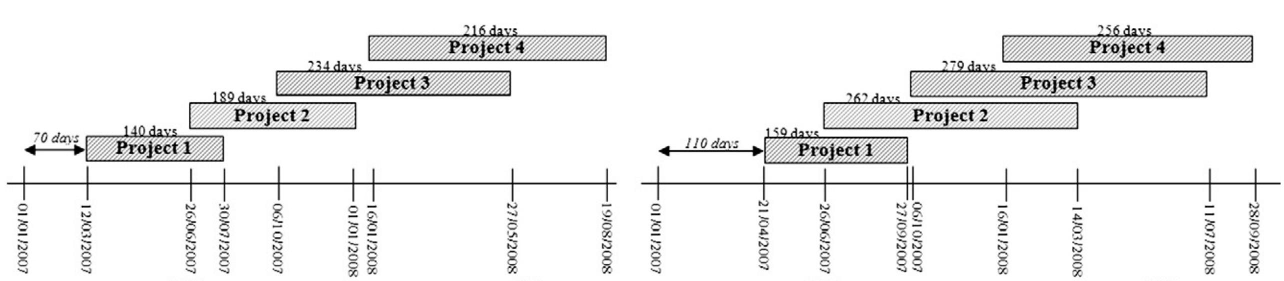


Fig. 10. Simulation experiments for 70 and 110 days delays in the start of project 1.

no free resource capacity can deteriorate permanently the multi-project organization's capability to deliver projects on time. Importantly, this insight suggests that best practice in single-project management, notably upfront planning and strategizing (Morris, 1994; Repenning, 2001), can have limited benefits if top management ignores the deleterious long-term effects of 'hijacking' systematically resources from concurrent projects. Indeed, our fieldwork indicates a badly implemented schedule-driven project management policy can lead to disenchantment among project staff who, disheartened with (and powerless to change) top management's attitudes have no choice but to get accustomed to reactive but ineffective project management practice.

A second contribution is reinvigorating computer-based simulation in project management studies of multi-project organizations. These organizations are complex adaptive systems (Aritua et al., 2009). But despite the suitability of system dynamics to study complex systems (Sterman, 1994, 2000), its use and the use of computer-based simulation more generally is rare in recent literature — Laslo and Goldberg (2008) is the exception. Our combination of in-depth fieldwork and computer-based simulation therefore introduces methodological diversity, and responds to recent calls for in-depth empirical and analytical studies of project performance in multi-project organizations.

This study has also important contributions to practice. First, we believe its managerial insights and product outputs may be useful to help persuade multi-project organizations to stop rewarding top management on the basis of their ability to implement short-term fixes regardless of their negative, long-term impacts to the organization's performance. Our results show instead that multi-project organizations need to put in place incentives and rewards that ensure top management keeps a holistic view. Such view can contribute to ensure top management is mindful of the importance of negotiating project budgets and resource allocations within the planned timescales so as to avoid pushing back new projects. To be effective, top and middle management need to be capable to forge consensus, a pre-requisite for high-performing multi-project organizations (Laslo and Goldberg, 2008).

And second, our results suggest that top management want to proactively keep some free capacity in regards to specialized resources. Like investments in product flexibility (de Neufville and Scholtes, 2011), organizations ought to frame an investment in free resource capacity as acquiring an insurance against future eventualities. This investment will then pay off whenever a critical project becomes unexpectedly under schedule pressure. Taken together, these insights also suggest firms need to supplement investments in training, processes, and education to improve single-project management with commensurate investments focused on managing multi-project environments.

### 6.1. Limitations and outlook

Like all studies, ours has limitations that open up opportunities for future research. First, the characteristics of the empirical setting informing the simulation model limit the external validity of this study. As a manufacturer of high-performance trucks operating in a competitive market, Alpha is developing constantly new variants and configuration options. Albeit incremental, these projects are undertaken by skilled resources that take time to recruit even when organizations are not reluctant to hire. These conditions are core to Alpha's multi-project nature, and qualify the generalizability of our insights. More studies are needed to falsify their validity into dissimilar multi-project settings.

Second, the simulation model also merits further development. Noteworthy, the simulation provides a stylised representation of a multi-project environment. Specifically, it simulates projects as if consisting of only one stage when a thorough analysis of Alpha's stage and gate model (Cooper, 1990) reveals six main stages and seven gates, each stage arguably requiring different resources. The simulation also does not capture the interfaces between Alpha's development division and its numerous product development suppliers, nor technical interdependencies between the project outputs and inputs. It therefore remains indeterminate how inter-firm relationships and technical interdependences between projects affect responses to schedule pressure.

Third, we incorporated in the model some analytical assumptions for the sake of tractability which can be relaxed in future studies. For instance, the simulation assumes that when the start of the first project is delayed, its target deadline remains unchanged. We also assume that a tardy project will capture resources from a concurrent project irrespectively of the negative impacts to that project. These assumptions are grounded on fieldwork. Admittedly, however, other organizations can operate under more flexible policies (Canonico and Söderlund, 2010), or can empower project managers to oppose attempts to hijack resources from their teams (Jonas, 2010). Project leadership capabilities can also be essential to pre-empt conflict between top management and middle managers around budgets and resource allocations (Kaulio, 2008; Laslo and Goldberg, 2008). It thus merits exploring how alternative policies and soft variables impact long-term project scheduling performance in multi-project environments.

In conclusion, we should further note that our model assesses project priorities based only on schedule pressure and focuses on how resource capturing affects project scheduling reliability. However, the organization's ability to meet planned project milestones is but one dimension of its overall performance. Arguably, in some instances, the revenue from overcoming an otherwise delay of a business-critical project that started late may offset the delay expenses stemming from disrupting other project deliveries. Organizations may also be able to mitigate the risk of declining work productivity, at least partly, when resources move between projects, a scenario not accounted for in this research. Future studies should therefore build in a set of priority rules and risk mitigation procedures that enable a comprehensive assessment of the trade-offs with implementing a schedule-driven project management policy in multi-project organizations.

## Appendix I. Questions for semi-structured interviews

**Warm-up**

- What is your job role and where are you located?
- Which projects have you been involved with?
- You mentioned project XXX- why was this project started?
- Can you elaborate on the history of this project?

**Exploration**

- What difficulties did you face in this project?
- You mentioned the influence of project XXX on your project, what is the connection of that project with your project?
- You mentioned this particular issue in the project; which factors do you think caused this issue?

**Sharpened**

- My research is about NPD projects unfolding under schedule pressure in a multi-project environment. What does schedule pressure mean to you?
- You mentioned decision ZZZ increased the schedule pressure in your project; can you elaborate on that?
- I found XXX causes YYY. But what do you think causes XXX to happen?

**Revising**

- Do you think the long timescale for making decisions explains the reason for the problem you mentioned?
- Some interviewees told me that XXX causes YYY. Would you agree?
- I learnt that YYY can happen in projects. Do you think this happens frequently in Alpha?

## Appendix II. Mathematical modeling and controls

The variables indicated in the stock and flow diagram in Fig. 4 are defined as follows:

$x_i$ "Project *i* Work-to-be-done" [work package]
$y_i$ "Project *i* Scope Delivered" [work package]
$p_i$ "Project *i* Progress" [work package/day]
$r_i$ "Project *i* Resources" [person]
$Pr$ "Productivity of the Resources" [unitless]

The Project Scope Delivered is a stock variable, and thus its value at any point in the simulation time is given by the integration of the flow rates connected to that stock:

$$\text{Project Scope Delivered}\,(y_i)\ \text{at simulation time}\ t_1 = \int_{t=SST}^{t=t_1} p_i\,dt + c$$

where SST is the simulation start time and $c$ is the initial value of $y_i$. Unit of $c$ is [work package]. Likewise, the amount of project work to be done is expressed as:

$$\text{Project Work to-be-done}\,(x_i)\,\text{at simulation time}\ t_1 = d - \int_{t=SST}^{t=t_1} p_i dt$$

where $d$ is the initial value of $x_i$ and its unit is “work package”.

To express that the project progress rate ($p_i$) increases gradually upfront until a peak is reached and then declines gradually in the late stages, the conventional S-shaped representation of project progress, the following natural logarithm function was used:

$$p_i \equiv min(log_b(x_i), log_b(y_i)) \cdot r_i \cdot k \cdot Pr$$

where the $k$ constant [unitless] defines how fast one unit of resource can process one unit of work package, and the constant $b$ is the base of the logarithm. The productivity ($Pr$) was assumed equal across all projects at any point in time. Finally, the project priority for resource allocation purposes was defined through the Absolute Priority Index ($Apr_i$), and modeled with an exponential function:

$$Apr_i \equiv me^{(\alpha - z)/\beta}$$

where $z$ is the time left to the planned deadline, and the constants $m, \alpha, \beta$ define a standard exponential shape. The priority of a project relative to others is then determined using a Relative Priority Index: $Rpr_i \equiv Apr_i \Big/ \left( \sum_{j=1}^{n} Apr_j \right)$. A detailed description of the mathematical model is publicly available at [reference hidden for review purposes]. To perform the simulation experiments, these mathematical variables and relationships were consolidated in user-friendly dashboards such as the one illustrated below.

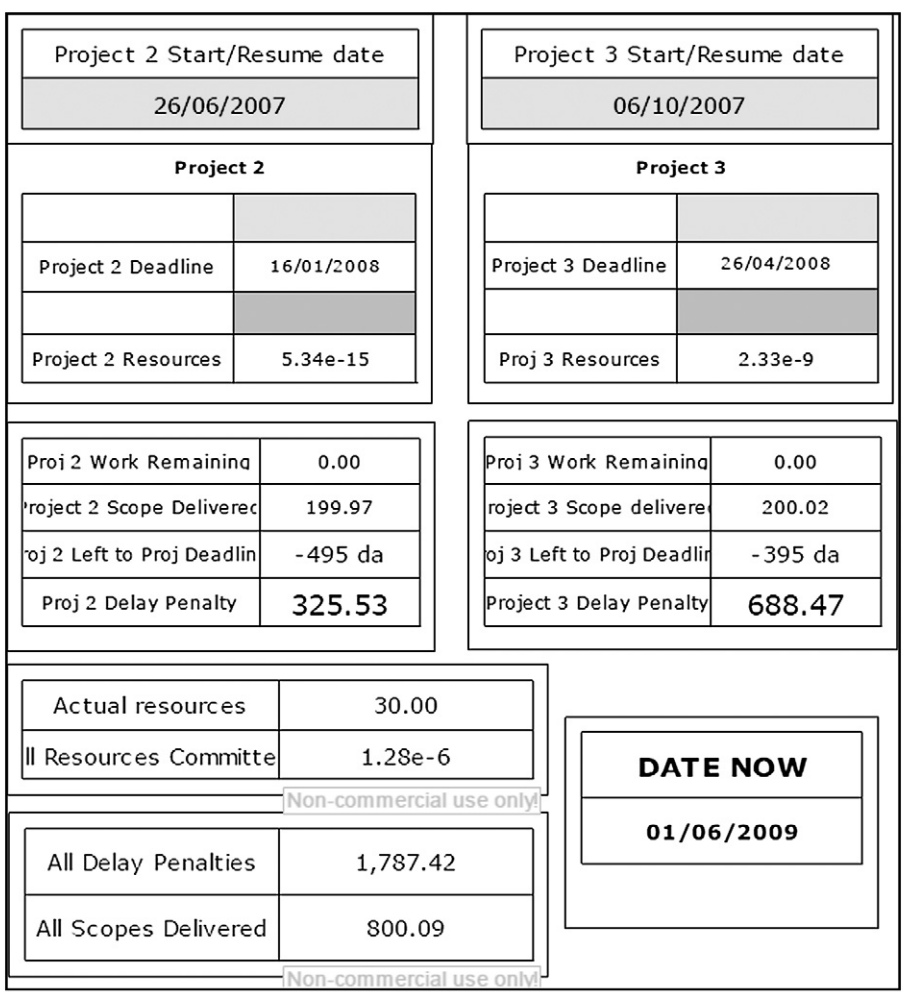


Fig. A.1. Example of the control dashboard for the simulation model.

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