Project Dynamics: Emerging Insights & Opportunities for the Future of Project Management Theory & Practice

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Contents

1.1 Abstract

Companies and individuals searching for revolutionary advances to enhancing their project management competencies have started applying project dynamics concepts and tools on their projects both across the world and increasingly in India. Project Dynamics, as emerging from the field of system dynamics, provides a radical, exciting approach that has begun to create new insights and initiate new advances in project management. This paper emphasizes the growth of project dynamics in setting new standards for excellence in project management through a transformation of the understanding of dynamics resulting from project features, rework cycles, reinforcing and balancing feedback, and the unintended consequences of project control strategies that create adverse dynamics. The paper (a) discusses the project dynamics approach from a structural and behavioural perspective, (b) highlights applications of project dynamics like post-mortem project evaluations and dispute resolution, estimation and risk assessment, project control, change management, and organisational learning, (c) presents strategic policy insights and directions for the future of project management theory and practice, and (d) presents the agenda and initial findings of a new study to integrate project dynamics within the PMI project management framework. The results of this study will help project management professionals and managers incorporate project dynamics concepts and tools in their practice and succeed in implementing the insights gained from a greater understanding of dynamics for superior performance on projects.

1.2 Keywords:

project management, project dynamics, project strategy, system dynamics, PMBoK

1.3 Introduction

In recent times, project management has been gaining in strategic importance for both industry and government. The importance of being able to manage projects well has never been greater in these times of increased industrial density, globalisation, foreign investment, and the use of advanced technologies making projects larger in scope, technically more complex, and financially more critical. However, only one out of three projects achieve all four of their initial project requirements of budget, duration, quality and scope (McKinsey & Company, 2008). Projects frequently face cost overruns, completion delays, compromised quality, and reduced scope. A recent example is the Mumbai Sea-link project that was not only over-budget (project budget increased more than five-fold from Rs. 300 crores to over Rs. 1,634 crores), was significantly delayed (by 5 years from a launch date of 2004 to 2009) and had to manage scope delivery to make the project launch in 2009 with 4 lanes instead of 8; the further four lanes were finally launched yet another year later in 2010. International examples of poor project performance, like the Channel Tunnel and the Boston Big Dig, demonstrate that poor project success rates are not endemic to a particular region but are a universal phenomenon.

In a recent online project management forum, when asked what was the biggest problem facing project management, managers across the world provided over 900 responses indicating that projects usually failed to meet their initial success criteria due to contributing factors like poor estimation during planning, changes in scope throughout execution, underestimating the complexity of implementation, and rework (due to errors) that is discovered while monitoring the project. Even with the best laid plans, managers need to continually exercise control decisions to address deviations of the project from its plan. Therefore, managers look for combinations of project control interventions to bring a project back to meeting its targets with the least adverse consequences. However, different amounts, durations and orders of application of such project control decisions impact project performance in different ways and cause problems of their own.

Some of the commonly recurring war stories from project managers are shared below:

- Even after well defined plans, managers find that due to unanticipated errors a significant amount of rework is generated that also needs to be completed in addition to the initial estimates of work. Such rework, when discovered in time, can still however be addressed but when it goes undiscovered causes even further rework downstream in subsequent phases of projects. To further compound the problem, fixing the errors often requires more work than doing the work in the first place – this is especially true when downstream work is contaminated by undiscovered upstream errors.

- Common interventions possible when project deadlines begin to slip are to increase overtime, hire additional people onto the project team, and to increase the pressure on the team to speed up the work being completed. In practice, various combinations of these three options are used as considered appropriate by project managers. However, it is often noticed by managers that these interventions cause other unintended effects as well. Overtime often works well in the short term to accelerate work done but in the longer term it leads to fatigue of the team. Errors then begin to increase leading to additional rework and therefore lower productivity. Using overtime even beyond this leads to worker burnout and often attrition.

- Increasing the project team size is a another popularly used intervention when projects find themselves behind schedule. However, adding people midway through a project can dilute experience as workers with less skill or less familiarity with the project are brought on, they require time from experienced team members to bring them up to speed, and communication overheads grow exponentially with the number of stakeholders. Sometimes the unavailability of experienced persons to bring onto the project precludes the use of this option itself. Experience dilution and increased communications often increase errors, decrease the pace of work and decrease productivity.

- The third option of increasing work pressure also often leads to increasing errors as haste makes waste – thereby increasing rework and reducing productivity. It is clear from the above that the very decisions intended to increase productivity and speed up progress by increasing overtime, adding people, or increasing work intensity often achieve exactly the opposite result due to the unintended consequences of these decisions. Project managers often relate that their projects seem to be a system with ‘a mind of its own’ where the system itself offers resistance to their efforts to control it.

- Another interesting intervention by project managers to combat milestone slippage is to try and increase the concurrency of activities on projects over and above the initial plan. However, as the initial project plan is modified and more concurrencies are attempted, often work starts to be done out of sequence leading to increasing errors and rework, and reducing productivity. These errors then cause further errors downstream if not discovered and corrected in time.

- External factors, like changes in scope or requirements by the client, often activate a variety of project control interventions by managers leading to internal dynamics as described above thereby ruining projects that were otherwise successful.

The unintended consequences of managerial decisions like increasing error rates, increasing rework and worker fatigue leads to morale and motivation problems, which when unchecked, sometimes leads to a sense of frustration and hopelessness on projects and eventually turnover leading to further workforce issues.

While managers are quick to recognise the effects described above as commonly occurring on projects, they find it difficult to understand the nature and strength of the interrelationships within the project 'system' and how they differ both within a particular project phase, between two different phases or on different projects. Moreover, this has led to managers seeking better approaches to measure the impact of different decisions to help them design superior interventions that achieve project milestones with greater speed, less cost, and better quality without compromising scope.

We look at the issues and challenges that managers have to deal with on projects along the two dimensions of detail complexity and dynamic complexity.

1.3.1 Detail complexity

Project managers, especially on large, complex projects, routinely use the existing state-of-the-art in project management tools, techniques and decision support software. While existing project management tools are pervasive in their usage, they largely deal with the static features, i.e. detail complexity, of projects. However, most project managers do not effectively understand or utilise the dynamic features of project processes like feedback, time delays, and non-linear cause-effect relationships between project components (Sterman 1992; Brooks 1978).

Commonly used tools like the Program Evaluation and Review Technique (PERT), the Critical Path Method (CPM), related work breakdown structure (WBS) tools and component cost estimating are widely used to manage development projects. However the limitations of such tools to address project issues like undiscovered rework, bilaterally coupled activities involving feedback and iteration, and time-varying and endogenous factors (like skill, training and coordination) make them inadequate to model the highly coupled aspects and dynamic nature of the development process (Ford 1995).

Apart from industry tools, the existing project management literature, e.g. the Project Management Body of Knowledge (PMBOK®) by the Project Management Institute (PMI) and world recognised professional certifications like the Project Management Professional (PMP®) offer excellent frameworks to manage detail complexity on projects (Project Management Institute 2008). The PMI provides a common language of project management that promotes learning, communication, creation of insights, and replication of successes on projects. Wide acceptance of this common language has led to huge advances in thought leadership and the project management field has now reached the stage where exponential growth and significant advances are possible in the way projects are managed in practice.

1.3.2 Dynamic complexity

In addition to the detail complexities of multiple resources, timelines, technologies, and targets, now we can also address the interdependencies between them and examine how those interdependencies change over time – leading to a transformation in our understanding of the dynamic complexity on projects as well.

Similar to the advances in the theory of project management, areas of research from other disciplines, like system dynamics and systems thinking, explicitly study the dynamic behaviour that arises from process structures (Choudhari 1997). These disciplines have helped in the development of new tools and techniques to help study the dynamic aspects of project behaviour (Forrester 1961, 1968; Senge 1990). These new tools often include the use of computer software and simulation to aid managers in coping with problems that arise from dynamic complexity. The project dynamics approach provides a new, promising approach to understanding the dynamics of change on projects, and we discuss this approach next and how it can be used to inform the theory and practice of project management.

1.4 The Project Dynamics Approach

Project dynamics is the study of the dynamics that occurs on projects. Project dynamics presents a rigorous way to help thinking, visualising, sharing, and communicating the relationships and interdependencies between various components of a project and how these causal relationships determine behaviour of the project over time. By creating operational maps and simulation models which articulate manager's 'mental models' and capture the interrelationships of physical and behavioural processes, internal and external factors, policies, information feedback and time delays, and by using these models to test alternative strategies, project dynamics helps solve project problems and create more robust project management architectures.

Project dynamics and related system dynamics literature provides a rich source of research and studies into the performance of projects with emphasis on dynamic behaviour and the underlying structural determinants of behaviour. The studies in project dynamics could be grouped into four primary classes or meta-structures of models that cover project features, rework cycles, project control strategies including their anticipated and unintended consequences, and the cascading and subsequent effects of decisions during projects.

We discuss these four classes of models and present some of them in the form of causal loop diagrams to provide the means for dialogue and communication of the project issues and relate the project dynamics models to the aforementioned war stories of project managers.

1.4.1 Project Features

Projects generally comprise of activities that are performed sequentially and concurrently. Therefore, like most project models, project dynamics models also include a representation of the actual activities and tasks on projects. Specific processes within a phase, various phases of a project, multiple projects in a program and their interdependencies can be modelled as they would exist in practice. Material flows, like lines of code, and information flows, like information available for decision making at a point in the system, are modelled explicitly along with the business policies that determine how that information is used to make decisions. Based on management perception of conditions at that point, resources are applied to manage the development processes on a project (Ford and Sterman 1998; Joglekar and Ford 2005).

Where project dynamics models get interesting and add new value is when they represent the perception gaps for managers, underestimation of scope and resources required, and include features that represent the human aspects of projects. There is often a difference between real progress and perceived progress of a project due to perception delays, lack of accurate information and undiscovered errors. Such errors also cause misallocation of resources that lead to performance problems. Human aspects like employee motivation when explicitly modelled add a new dimension of planning to projects. Modelling important components of actual projects increases the ability to simulate realistic project dynamics that relate directly to the experiences of practicing managers.

Finally, companies are now using project dynamics models with increasing levels of sophistication and detail by including features like distinguishing work done correctly from work done incorrectly, multiple project phases, separate quality assurance efforts, nonlinear constraints of work availability on progress, development projects as value-adding aging chains, overlapping activities and concurrence constraints, design changes and uncertainties, releasing of completed work with unrecognised errors to downstream phases, the use of contingency funds, schedule buffers and various resource allocation policies.

When used in a complementary manner to the PMI frameworks, these project feature models add significantly to the understanding of the dynamic complexities on projects and enhance the ability of managers to make decisions when confronted with perception gaps, delays in processes, and nonlinear relationships that change over the course of the project.

1.4.2 Rework Cycles

Rework cycles are one of the most important features of project dynamics models. The rework cycle occurs on projects when errors caused by doing work incorrectly results in having to do additional work to correct the errors or in redoing the work completely. However, as rework is done, the rework itself also tends to have errors causing further rework. Rework cycles are caused by this recursive nature of rework in which errors create rework which generates more errors that creates further rework, thereby creating problematic behaviours that often stretch out over most of a project's duration and are the source of many project management challenges (Ford and Sterman 2003).

Whether rework arrives unanticipated, or it is expected and estimated, or it is suddenly generated by external factors, it causes severe challenges for project managers. When rework is caused by unanticipated errors, project managers find that their project estimates have not accounted for or budgeted for this rework. Even when the fraction of rework is estimated and planned for on a project usually from past experiences with similar projects or statistical baselines from data collected on previous projects, the recursive compounding of rework is often underestimated. Furthermore, even with anticipated rates of rework, errors are seldom discovered immediately and there is usually a time delay between errors being generated and being detected either during testing or downstream at subsequent stages on a project. Finally, rework is very often triggered by external factors, like client changes in requirements. In this case, a project that was well on track earlier could easily be derailed due to the additional rework cycles created due to the externally generated changes.

Project dynamics provides the concepts to better understand the cyclical nature of rework and the methodology to estimate more accurately the effort required due to rework cycles. Current models of rework include quality assurance activities, parallel cycles to distinguish between whether rework was created by current or upstream phases and whether rework occurs due to correcting flawed work or is initiated to respond to externally generated changes.

As an introductory example to the use of a common diagramming technique of project dynamics called causal loop diagramming, we present Figure 1: Project Rework Structure. The causal loop diagram below represents the cause and effect relationships on a project that interrelate to create dependencies and generate the rework cycles on projects.

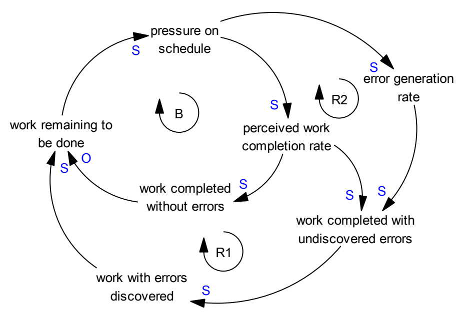

Figure 1: Project Rework Structure

The first feedback cycle is a balancing loop (labelled B) where a larger amount of *work remaining to be done* causes an increased work *pressure on schedule* which in turn causes the *perceived work completion rate* also to increase similarly leading to an increased amount of *work completed without errors* and this has an opposite effect, i.e. it decreases the *work remaining to be done*.[1] The second feedback cycle is a reinforcing loop (labelled R1) that shows that while the *perceived work completion rate* is increasing the *work completed with undiscovered errors* is also increasing similarly ('s' on the arrowhead) which after a time delay during which testing and quality assurance is carried out the amount of *work with errors discovered* increases. This leads to more *work remaining to be done*, i.e. rework. The additional *work remaining to be done* leads to further *pressure on schedule* which leads to more work being completed albeit with undiscovered errors creating this reinforcing cycle. The final reinforcing loop R2 indicates that when *pressure on schedule* increases, this leads to additional stress on the team and the *error generation rate* increases leading to an increase in the *work completed with undiscovered errors*. While the first balancing loop B represents the progress of work being done on a project without errors or rework, the reinforcing loops R1 and R2 represent the effects of rework being created and the effects of schedule pressure to increase errors (and therefore rework) on a project respectively.

1.4.3 Project Control Strategies

The performance of a project is typically measured along the dimensions of schedule, cost, and quality for the scope to be delivered. Through the course of project, managers make decisions to control the performance gap between actual progress of

[1] An 's' near the arrowhead indicates that two factors mentioned at both ends of that arrow move in *similar* directions, while an 'o' indicates that the two factors move in *opposite* directions.

the project and the performance targets set for the dimensions above (Lyneis et. al 2001; Abdel-Hamid and Madnick 1991). However, as human beings, managers make decisions based on what they perceive and what information is available to them at that point in time. A unique aspect of project dynamics models is that they differentiate between perceived conditions and actual conditions on a project. The perceived conditions drive project control actions by managers and the actual conditions drive actual progress on projects. Project dynamics models that include aspects of information availability and human decision making help managers make better forecasts of project performance, and thereby make more informed project control actions.

An example from our previous discussion on rework shows that managers generally include undiscovered rework in the work they perceive as completed as the errors are as yet undetected at that point in time. This often leads to overestimating progress and productivity at the early stages of a project. So while the actual progress made is less than it seems due to work completed containing undetected errors, future decisions and forecasts are made based on the amount of work that is incorrectly perceived to be completed.

A causal loop diagram is shown in Figure 2 to represent common control actions by managers to address schedule slippage by increasing the labour resources on a project by using various interventions like increasing the work intensity, increasing overtime, and increasing the headcount on a project.

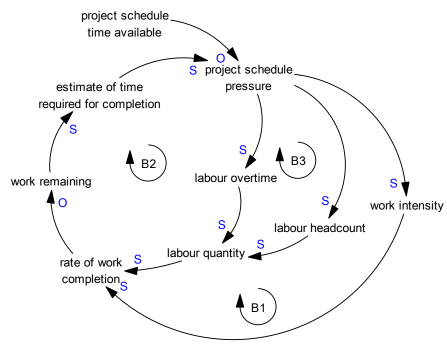

Figure 2: Project Labour Control Interventions

The balancing loop B1 shows that when *project schedule pressure* increases on a project due to the gap between *project schedule time available* and the *estimate of time required for completion*, as an intervention option, managers increase pressure on the project team to increase *work intensity* which then over time increases the *rate of work completion* leading to less *work remaining*. This in turn leads to a lower *estimate of time required for completion* of work and less *project schedule pressure*. The second type of intervention, viz. increasing overtime, is shown by the balancing loop B2, where an increase in *project schedule pressure* leads to increasing *labour overtime* which increases the effective amount of *labour quantity* available for the project leading to an increasing *rate of work completion*, less *work remaining*, a lower *estimate of time required for completion*, and subsequently less *project schedule pressure*. The third intervention of increasing headcount by adding people is shown by the balancing loop B3 where an increase in *project schedule pressure* leads to an increase in *labour headcount* leading to an increased *labour quantity* available to work on the project leading to more work being done and subsequently less schedule slippage.

Figure 2 above illustrates how project control actions, like labour control actions, act through the system to control the performance gaps (in this case the schedule pressure that arises from a gap between *estimate of time required for completion* and *project schedule time available*). However, a variety of project control strategies can be modelled explicitly in models and the subsequent results can be seen. While the causal loop diagram above illustrates conceptually how control actions work, managers also need to know the size and speed of the adjustments they should make, an indication of the costs vs. benefits of each intervention and tools to assist them with designing superior strategies to control schedule slippage. For the design of intervention strategies, we will later discuss how project dynamics provides additional methodologies and tools to build simulation models of the project where such strategies can be designed and tested.

1.4.4 Cascading and Subsequent Effects

From the common war stories of project managers, we've seen how frequently used project control actions like increasing overtime, adding people and increasing work pressures on a team can have counterintuitive and unintended consequences of exacerbating the very project conditions of schedule slippage that they seek to alleviate due to the feedback effects of increasing errors, increasing rework, experience dilution, communication overheads, fatigue, burnout and worker turnover.

Project dynamics literature often calls these cascading and subsequent effects *ripple effects* and *knock-on effects* and helps managers understand how these effects are created and how to avoid and alleviate them.

1.4.5 Ripple Effects

Ripple effects are the primary impacts of project control actions on rework and productivity and often include the dilution of experience levels, increased communication requirements, reduced productivity, lower quality and increased errors, and worker fatigue (Abdel-Hamid and Madnick 1991). We'll use the same example of labour control interventions as in Figure 2 to illustrate how well meaning project control actions create these undesired effects.

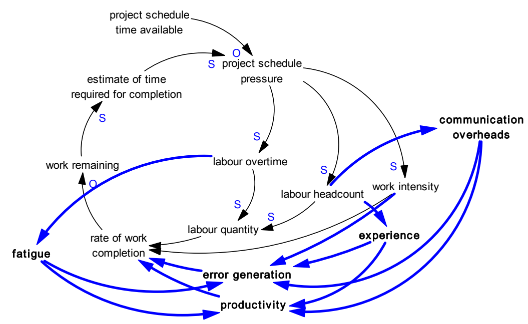

Figure 3: Cascading Ripple Effects of Project Labour Control Interventions

Figure 3 contains the same project control interventions as Figure 2. However, the unintended consequences of experience dilution, communication overheads and fatigue on error generation rates and productivity are added in the bolder links. By increasing *labour headcount*, i.e. adding new people midway on a project that either have less experience or at a minimum unfamiliar with the project, the *experience* levels of the team decreases leading to lower overall *productivity* and often increased *error generation* rates. Also, increasing headcount increases *communication overheads* exponentially and this leads to similar effects on *productivity* and *error generation* rates. Increasing *labour overtime* can be a suitable short term strategy but eventually leads to *fatigue* which then leads to lower *productivity* and increased *error generation* rates. Increased *work intensity* leads to increases in *error generation* rates as well. These compounding increases in *error generation* rates increases the additional rework required to be done and lower *productivity* decreases the *rate of work completion* thereby defeating the very intent of managers behind the project control interventions. From Figure 3, it is easy to see how these ripple effects add to the dynamic complexities of the project and make such projects difficult to manage.

1.4.6 Knock-on Effects

Project dynamics models further analyze the impacts of the above ripple effects as they in turn cause secondary and tertiary effects that include out-of-sequence work, error contamination, additional work and lower employee morale (Lyneis and Ford 2007) as shown in Figure 4.

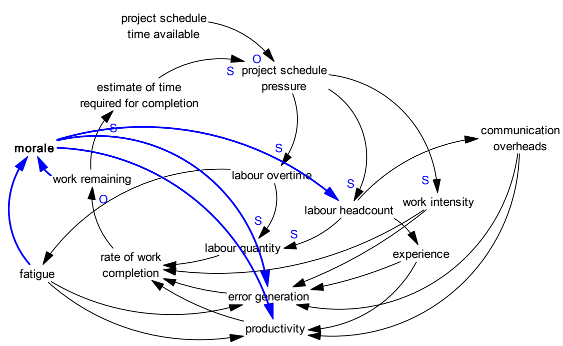

Figure 4: Subsequent Knock-on Effects of Project Labour Control Interventions

Figure 4 shows as an illustration one of these four subsequent knock-on effects of employee morale as affected by the impact of project control actions. As *fatigue* increases and the *work remaining* increases due to rework, employee *morale* begins to decrease leading to lower *productivity* and higher *error generation* rates. If low employee morale continues unchecked, it eventually results in employee turnover and lower experienced *labour headcount* on projects leading to further project problems. Other knock-on effects that are not shown in Figure 4 would include the impacts of using concurrency and overlapping activities on projects to reduce schedule slippage, knock-on effects of upstream errors causing errors downstream and tipping point effects where errors require more effort to fix than the original work required. If these causal loops were added to Figure 4, it is easy to see how the causal loop diagram, which is only a mapped representation of the project system, would be more complex and difficult to understand for managers.

While human beings are adept at specifying individual relationships between parts of a system, the human mind is not suited to understanding how all these parts interact simultaneously to create system performance. This is precisely one of the most significant contributions of project dynamics models where several relationships can be modelled by eliciting the information gained from managers' experience and resident in the mental models of the managers' mind and then simulated using computers to understand and plan for project performance. The models are only represented as causal loop diagrams above for transparency but using the language of project dynamics, these causal loop diagrams are meant to be modelled mathematically using stocks and flows on a computer. Models so developed can then be simulated on a computer and experimentation with a wide variety of inputs and policies are possible. The actual simulations reveal the working of the system behaviourally, and the underlying structures of the model can be studied by managers to understand the structural determinants of project behaviour. The models and simulations can be used by managers for experimentation to aid understanding and also to design specific project architectures, policies and interventions.

1.5 Applications of Project Dynamics

Project dynamics is growing in its usage both worldwide and in India and finds several applications in project management and allied activities on projects due to the depth of the investigation that is made possible because of these models. We discuss these applications here and, in the next section, we present directions for future work.

1.5.1 Estimation and Risk Assessment

The experiences of project managers and project data suggest strongly that often adverse project dynamics is caused by underestimating scope or under-budgeting for the estimated scope of work. Project dynamics models are now being used in conjunction with more traditional estimation approaches at three stages during a project: (1) Upfront, to adjust traditional estimates based on known or expected deviations (risks) from typical projects; (2) during the project, to determine the degree of any project underestimation earlier than would typically occur; and (3) after the project, to assess what the project should have cost had other decisions been taken, including better initial estimates.

Project dynamics has been used for risk assessment in two ways: (1) Post-project evaluations that determine the magnitude of changes that actually occurred on projects as a guide for what might occur on future projects; and (2) pre-project simulations that test the consequences of similar risks for the current project.

1.5.2 Project Control

Even with improved estimation, risk assessment and planning, projects will rarely go exactly as planned. Project dynamics helps managers understand how they should best respond with their project control actions when problems occur. As seen from our discussion above on labour project control strategies, project dynamics provides key lessons and insights for managers in areas like managing the rework and minimizing the ripple and knock-on effects of the project control interventions.

1.5.3 Risk Management

Project dynamics models have helped managers develop insights by focusing on risk management approaches instead of specific policies, e.g. models have been used to operationalise real options theory in projects for risk management. Project managers simultaneously seek project structures and policies that maximize project performance yet perform well when faced with a range of uncertainties that reflect risks. Project dynamics models show that managers who tailor polices for specific project assumptions can outperform those that manage for a wide range of conditions, if those project assumptions materialize. But if conditions deviate from those assumed by management, tailored policies generate much worse performance. Through simulation across various scenarios, these models help identify and address this fundamental trade-off between project robustness, i.e. the ability to perform well across a range of uncertain conditions, and performance under known specific conditions.

1.5.4 Project Evaluations and Dispute Resolution

Project dynamics models are often used for post-project assessment of projects to understand how and why the project deviated from the original plan. Most of these models are applied in situations involving disputes between the owner/financer of the project and the contractor/executer of the project. In many cases, such disputes involve claims of “delay and disruption” or in the project dynamics terminology, ripple and knock-on effects that result from problems on projects. These models are then used to quantify and explain the impact of deviations of the project on its final cost. The model can be set up to represent the project as it actually occurred, including the direct impacts, and calibrated to the actual performance of the project. It can also apportion costs to the client, to other parties, and to the contractor through simulations that involve removing different groups of direct impacts.

1.5.5 Change Management

When customers make changes to projects, the original plan almost always becomes infeasible. Change management entails pricing and mitigating proposed changes as they occur on an ongoing project (rather than waiting for disputes to occur after the project ends). Companies have used project dynamics models to assess optimal schedule extensions when changes are introduced on a project, examine the consequences of attempting to compress a project’s schedule, at the request of the client, and to forecast and mitigate change impacts, including quantifying the changes’ effects, diagnosing the causes, and planning and testing mitigating actions to reduce project costs

1.5.6 Individual and Organisational Learning

The ability of project dynamics models to clearly and richly explain how project structures and behaviour interact makes them effective for teaching project management. A number of the project models have been converted into gaming simulators for use in management training. After such a simulation, the reasons for simulated project performance are analyzed, usually with causal loop diagrams such as those developed above, and the diagnostic output from the models is used to understand the dynamic complexity of projects that the many causal relations create and to appreciate the challenges of project management.

1.6 Insights and Directions for Future Work

From the body of knowledge that is emerging from the various applications where project dynamics models are being built, managers are seeing several insights emerge from both the models as well as possibilities to incorporate the project dynamics approach into routine project management activities. These insights include a new awareness that project plans themselves sow the seeds for project success or failure even prior to execution, trying to achieve an overly aggressive plan often actually makes the performance of the project worse, recognising the existence of undiscovered rework and finding new ways to avoid its consequences, increasing early quality assurance even at lower initial productivity is generally beneficial to project outcomes, and prioritizing rework detection and correction over starting new work helps avoid downstream problems even though projects then seem to progress slower initially.

Where managers have used these models, they have learned that even if recognised and designed well, the project control actions (like those discussed above) are often difficult to implement because implementation initiates worse-before-better project behaviour. By effectively demonstrating any worse-before-better dynamics and the eventual benefits of implementation, a formal model can give managers the courage to stay the course with the execution of innovative and counterintuitive project plans (Graham et al, 2002).

While managers find the use of the project dynamics approach valuable when implemented, they sometimes find it difficult to initiate use of the approach for the first time with their project teams. One of the primary limitations in the practical and extensive use of project dynamics modelling is that many of the tools (which are usually computer-based) are often found by managers to be both complicated to understand and difficult to use in practice. So there is a need to be able to simplify and translate from this field of study to create practical and easily usable frameworks, and develop insights and 'lessons learned' to assist managers on their daily managerial decisions. Furthermore, managers see the need to integrate the project dynamics approach within the more familiar and traditionally accepted approaches and frameworks for project management like, for example, work breakdown structures, critical path modelling, and component cost estimating.

Therefore, as directions for future work, we propose that the *theory* of project management would be enhanced by integrating research from the two different areas of traditional project management and project dynamics and that the *practice* of project management could be better informed by developing a model that can be used for experimentation and to develop insights that can aid managers' decisions during actual project situations. In the next section, we outline the agenda and initial findings of a new study that proposes to meet these two objectives by integrating project dynamics insights within the PMI project management framework.

1.7 Project Dynamics Integration Study

To meet the two needs of developing a better understanding of the dynamic complexities on projects and augmenting the decision making ability of managers in practice, the utility of the study proposed is three-fold: (a) To improve the understanding of project management by incorporating insights from project dynamics within the commonly used PMI project management frameworks, (b) to build a model that can be used for experimentation and development of strategic decision making insights that will help managers improve performance on projects, and (c) to obtain experiential industry feedback and contextual support for the model and its findings through field studies with project managers.

The initial findings of this project dynamics integration study can be grouped under three areas:

1.7.1 Improved Understanding of Project Dynamics

The insights from project dynamics, and their relevance to the practice of project management, are enhanced by integrating the findings of research from project dynamics into the body of knowledge that is used by project management practitioners. By relating the varied project processes, resources, decisions, scope and performance targets into a single model, this study has begun the groundwork to present a new tool for project managers to investigate the dynamics of projects.

1.7.2 Development of Model for Decision Making

To cross the bridge from research to practice, this study will provide utility to the practice of project management by developing a model for experimentation that is intended to help managers make better project control and management decisions. The model presented in this study represents several detailed hypotheses (like tradeoffs of cost vs. schedule, impact of rework, and the like) and assumptions about policies and decision making – these can be validated or alternative policies can be defined and experimented with using the model developed in this study. The model is expected to have significant utility for field managers as through the use of and experimentation with the model, managers will enrich their mental models by giving them insights into the systemic causes of success and failure on projects (Senge, 1990).

1.7.3 Contextual Feedback

Project management is required in a variety of classes of projects, like construction, software, new product development, and the like; however, the empirical portion of this study has focused on one industry, viz., the construction industry and aims to enumerate the contextual and situational factors that determine the utility of the model and its findings for project managers in this industry. The findings of this study will be used to obtain contextual feedback from project managers on construction projects, and by doing so, enhance the applicability of the lessons learned within the context of the construction industry. The model so developed will eventually be converted into a management simulator and provided to all participants of the study to benefit from the opportunity to experiment with and develop their own insights from the model developed.

1.8 Conclusions

Project dynamics represents an exciting approach to transform the way project managers think about their projects, transform their ability to direct and control projects, and transform the levels of eventual project performance. The applications of project dynamics models are increasing as is evidenced from the fact that models are increasingly being built and used by companies for a variety of purposes from defining project strategy to estimation to post-mortem evaluations to dispute resolution. The usage of the project dynamics approach by managers can be enhanced by integration of the project dynamics approach within the widely accepted PMI frameworks and the PMBOK. The study to integrate these approaches and frameworks is currently underway and promises to help both academicians and managers better understand the emerging insights and opportunities for the future of project management theory and practice.

1.9 References

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1.10 Author's Profile

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