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Project Dynamics

Research Project Descriptions

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Project Controls to Minimize Cost and Schedule Overruns: A Model, Research Agenda, and Initial Results

David N. Ford, James M. Lyneis, and Timothy R.B. Taylor

System dynamics has been successfully applied to the study of projects for many years. While this modeling has clearly defined the structures which create project dynamics, it has been less helpful in providing explicit policy advice to managers to control project performance. To address this gap we examine the impact of three common project controls available to project managers to address deviations in project performance; (1) exerting pressure on project staff to work faster, (2) having staff work overtime, and/or (3) hiring additional staff. While the three project controls can have short-term benefits for project performance their long-term impacts can be detrimental. The current work presents preliminary results of the research, focusing on the impacts of the three project controls on project rework and the resulting schedule and budget performance. The work describes the development of project control feedback structures, the initial testing and use of a formal system dynamics model of the system, and preliminary results. The work concludes with a description of future project research efforts

Lyneis, J. M. and Ford, D.N., Taylor, TR. "A Project Control Model". Proceedings of the 2007 International System Dynamics Conference, Boston, Ma. July 23-27, 2007.

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System Dynamics Applied to Project Management: A Survey, Assessment, and Directions for Future Research

James M. Lyneis and David N. Ford

One of the most successful areas for the application of system dynamics has been project management. Measured in terms of new system dynamics theory, new and improved model structures, number of applications, number of practitioners, value of consulting revenues, and value to clients, "project dynamics" stands as an example of success in the field. This paper reviews the history of project management applications in the context of the underlying structures that create adverse dynamics and their application to specific areas of project management, synthesizes the policy messages, and provides directions for future research and writing.

Keywords: system dynamics, project management

Lyneis, JM and Ford, DN, "System Dynamics Applied to Project Management: A survey, assessment, and directions for future research". System Dynamics Review, Vol. 23, No. 4 pp. 157-189. Winter, 2007.

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Effects of Resource Allocation Policy Design for Reducing Project Durations: A Systems Modeling Approach

Zeewoon Lee, David N. Ford, and Nitin Joglekar

Minimizing duration is critical to success in many development projects. Resource allocation policies during such projects determine the fractions of resources that are to be assigned to constituent tasks. The choice of allocation policy can strongly influence project durations. But policies for reduced project duration are difficult to design and implement because of closed loop flows of work that generate dynamic demand patterns and delays in shifting resources among activities. Resource demand estimates and resource adjustment times are two policy features that managers can readily alter to influence project durations. These features are used to describe robust allocation policies in a relatively simple project model. Myopic and foresighted policies are distinguished by their use (or lack thereof) of rework and multiple backlogs in allocation. Optimal policies under perfect and limited managerial control are described by testing myopic and foresighted policies across a range of project complexities and adjustment times under deterministic and uncertain conditions. Counter-intuitive results from this analysis indicates that minimum resource allocation delay does not produce minimum durations, and increasing uncertainty decreases durations under certain conditions. The model is used to explain these results. Managerial implications and future research topics are discussed.

Keywords: system analysis, resource allocation, policy design, policy analysis, project management, product development, foresight, delay, system dynamics

Lee, Z, Ford, D.N. and Joglekar, N. "Effects of Resource Allocation Policy Design for Reducing Project Durations: A Systems Modeling Approach" Systems Research and Behavioral Science". Vol. 24, No. 6, pp. 551 to 566. Nov-Dec 2007.

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Project Management Quality and the Value of Flexible Strategies

David N. Ford and Shilpa Bhargav

Construction strategies for competitive bidding and operations are used to avoid the consequences of poor schedule performance such as delay penalties. Flexible strategies in the form of options can increase project value if uncertain conditions cannot be adequately forecasted before operations begin. However, project management purposefully manipulates the project performance that drives the use of options and thereby the value added by options. Therefore project management quality may influence option values. This research investigates the interaction of project management and option value by operationalizing a common use of real options in construction and valuing the option with different levels of project management quality. A simple but realistic dynamic simulation model of a project is described and exercised to reveal some impacts of project management on option value. Results support a hypothesis that increased project management quality decreases option value and that real options in managing construction projects can be explained with real options theory. The model structure suggests causal explanations that are consistent with real options theory. Results suggest that practicing managers can significantly increase project value by structuring managerial flexibility and thereby improving their evaluation, development, and use of flexibility. However, ignoring the multiple means of managing uncertainty that are often available can distort valuation. Results also suggest that researchers of strategic flexibility in projects should consider multiple forms of uncertainty in modeling options. Increasing the number of available options or the effectiveness of options in a multiple-option environment can decrease individual option values.

Keywords: flexibility, real options, risk management, project management, system dynamics, strategy

Ford, DN and Bhargav, S "Project Management Quality and the Value of Flexible Strategies Engineering", Construction and Architectural Management, Vol. 13, No. 3.pp. 275-289. Spring, 2006.

NOTE: This paper won the "Highly Commended" Award of Excellence from Emerald Literati Network 2007

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Tipping Point Failure and Robustness in Single Development Projects System Dynamics Review

Timothy R. B. Taylor and David N. Ford

Tipping points can push a series of product development projects into fire-fighting mode in which rework overwhelms progress. Similar dynamics also threaten the performance of individual development projects. The current work extends previous tipping point dynamics research to single projects and demonstrates how a simple, common feedback structure can cause complex tipping point dynamics, trap projects in deteriorating modes of behavior, and cause projects to fail. The model is based on previous system dynamics project models and validated with data from nuclear power plant construction projects. Basic tipping point dynamics in single projects are described, demonstrated, and analyzed with the model. System robustness to tipping point-induced failure is quantified and project features analyzed with sensitivity analysis for their impact on robustness. Several strategies for managing projects near tipping points are tested. Successful strategies include, tipping point avoidance through project design, forecasting resource demand, and fast resource adjustments. Managerial implications and research opportunities are discussed.

Keywords: project management, tipping point, robustness, loop dominance, scope creep, contamination, resource allocation, system dynamics

Taylor, T. and Ford, D.N. “Tipping Point Failure and Robustness in Single Development Projects System Dynamics Review”. Vol. 22, No. 1. pp. 51-71. Spring, 2006.

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Adapting Real Options to New Product Development by Modeling the Second Toyota Paradox

David N. Ford and Durward Sobek

Uncertainty in product development projects creates significant challenges for managers who are under intense competitive pressures to increase product quality while reducing development time and costs. Traditional wisdom dictates the early selection of a single design in order to freeze interfaces between product subsystems so that team members can work effectively in parallel, resulting in more productive product development efforts. Prior research, however, uncovered a paradoxical case. Toyota Motor Corporation achieves the fastest development times in its industry by intentionally delaying alternative selection, a strategy termed set-based development. The current work adapts real options concepts to product development management to partially explain this paradox. A formal simulation model is used to show that converging too quickly or too slowly degrades project value. Furthermore, the model demonstrates that the wisdom of set-based strategies can be explained by the application of a real options approach to product development management. Implications for managers and directions for future work are discussed.

Keywords: flexibility, product development, project management, real options, risk management, set-based concurrent engineering, system dynamics

Ford, D.N. and Sobek, D.N. “Adapting real options to new product development by modeling the second Toyota Paradox” IEEE Transactions on Engineering Management. Vol. 52, No. 2, pp. 1-11. May, 2005.

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Product Development Resource Allocation with Foresight

Nitin R. Joglekar and David N. Ford

Shortening project duration is critical to product development project success in many industries. As a primary driver of progress and an effective management tool, resource allocation among development activities can strongly influence project duration. Effective allocation is difficult due to the inherent closed loop flow of development work and the dynamic demand patterns of work backlogs. The Resource Allocation Policy Matrix is proposed as a means of describing resource allocation policies in dynamic systems. Simple system dynamics and control theoretic models of resource allocation in a product development context are developed. The control theory model is used to specify a foresighted policy, which is tested with the system dynamics model. The benefits of foresight are found to reduce with increasing complexity. Process concurrence is found to potentially reverse the impact of foresight on project duration. The model structure is used to explain these results and future research topics are discussed.

Keywords: concurrent development, control theory, forecasting, product development, project management and scheduling, resource allocation, rework cycle, system dynamics

Joglekar, N. and Ford, D.N., "Product Development Resource Allocation with Foresight" European Journal of Operational Research. Vol. 160 No. 1, pp.72-87. Jan., 2005.

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Managing Constructability Reviews to Reduce Highway Project Durations

David N. Ford, Stuart D. Anderson, Andrew J. Damron, Rodrigo de Las Casas, Nevzat Gokmen, and Steven T. Kuennen

Highway project durations that are longer than necessary delay the delivery of benefits to road users. Budget constraints often preclude the use of additional funds to shorten total project duration. Therefore, state highway agencies seek ways to decrease construction project durations without increasing costs. Research has recommended formal constructability reviews as an effective approach to meeting this goal. Formalized constructability reviews have been effective in isolated cases but only about one-quarter of state highway agencies currently have a formal constructability review program. An inadequate understanding of implementation issues, including the effective use of resources, is a potential cause. The effects of constructability reviews on the design phase, construction phase, and project durations are modeled and analyzed. Results illustrate and explain how intermediate-sized constructability reviews reduce project durations more than very large or small reviews and the potential impacts of a design-build approach on constructability review effectiveness.

Keywords: constructability, design-build, design review, project management, schedule performance, simulation, system dynamics

Ford, D.N., Anderson, S., Damron, A., de Las Casas, R., Gokmen, N. and Kuennen, S., “Managing Constructability Reviews to Reduce Highway Project Durations” ASCE Journal of Construction Engineering and Management. Vol. 130, No. 1, pp. 33-42. January, 2004.

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The Liar's Club: Impacts of Concealment in Concurrent Development Projects

David N. Ford and John D. Sterman

Successfully implementing concurrent development has proven difficult for many organizations. However, many theories addressing concurrent development treat either technical aspects of the development process (e.g., precedence relationships) or behavioral issues (e.g., creating effective cross-functional teams), but not their linkages. We argue that much of the complexity of concurrent development—and the implementation failures that plague many organizations—arises from interactions between the technical and behavioral dimensions. We use a dynamic project model that explicitly represents these interactions to investigate how a "Liar's Club"—concealing known rework requirements from managers and colleagues—can aggravate the "90% syndrome," a common form of schedule failure, and disproportionately degrade schedule performance and project quality. We discuss the role of the incentives on and behavior of engineers and managers in concurrent development failure and explore policies to improve project performance.

Keywords: concealment, concurrent development, concurrent engineering, cycle time, iteration, project management, rework, system dynamics

Ford, D.N. and Sterman, J. "The Liar's Club: Impacts of Concealment in Concurrent Development Projects" Concurrent Engineering Research and Applications. Vol. 11, No. 3, pp. 211-219, Sept., 2003.

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Overcoming the 90% Syndrome: Iteration Management in Concurrent Development Projects

David N. Ford and John D. Sterman

Successfully implementing concurrent development to reduce cycle time has proven difficult due to unanticipated iterations. We develop a dynamic project model that explicitly models these interactions to investigate the causes of the "90% syndrome," a common form of schedule failure in concurrent development. We find that increasing concurrence and common managerial responses to schedule pressure aggravate the syndrome and degrade schedule performance and project quality. We show how understanding of and policies to avoid the 90% syndrome require integration of the technical attributes of the project, the flows of information among participants, and the behavioral decision-making heuristics participants use to respond to unanticipated problems and perturbations.

Keywords: concurrent development, fast track, concurrent engineering, cycle time, iteration, project management, rework, system dynamics

Ford, D.N. and Sterman, J. "Overcoming the 90% Syndrome: Iteration Management in Concurrent Development Projects" Concurrent Engineering Research and Applications. Vol. 11, No. 3, pp. 177-186, Sept., 2003.

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Achieving Multiple Project Objectives through Contingency Management

David N. Ford

Project managers use budgets to satisfy multiple objectives such as cost control, short durations and high quality. Contingency funds are included in project budgets to manage risk and achieve project goals. Understanding how managers use budget contingencies requires a dynamic information processing model of how managers bridge the gap between high project complexity and limited managerial capacity. The results of collecting contingency management practices of real estate development project managers are reported and a dynamic simulation model of contingency management described. The model is used to test hypotheses of the effectiveness of aggressive and passive management strategies on cost, timeliness and facility value. Managers were found to pursue general project objectives in their management of contingency. An aggressive strategy was found to be more robust, but performed poorer, than a passive strategy. Implications for construction project management and future research opportunities are discussed.

Keywords: contingency, flexibility, project management, risk management, system dynamics

Ford, D. N. “Achieving Multiple Project Objectives through Contingency Management”. ASCE Journal of Construction Engineering and Management. 128(1): 30-39. February, 2002

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The Application of System Dynamics to Concurrent Engineering

David N. Ford

Concurrent Engineering or simultaneous engineering imposes a lot of challenges on the project manager to successfully finish the project on account of the diversity of actions and agents, and the relationships and interactions between each entity. The diversity and tight coupling of various components makes it impossible to understand and improve concurrent engineering if the sole focus is on individual entities. The system has to be analyzed from a holistic view considering all the causal paths between each activities. Being a complex system, effective modeling and analysis will assist the designers and managers of concurrent engineering to understand how different components influence each other in order to design changes that will improve the performance. The paper addresses use of system dynamics to model these causal relationships, resultant structural feedbacks and effects of policies implemented in the system.

Keywords: Concurrent engineering**,** System dynamics, structural feedbacks, causal relationships.

Ford, D.N. “The Application of System Dynamics to Concurrent Engineering,” *INSIGHT. International Council on Systems Engineering*. Vol. 2, No. 3, pp. 20 – 23, Fall, 1999.

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Dynamic Modeling of Product Development Processes

David N. Ford and John D. Sterman

Successful development projects are critical to success in many industries. To improve project performance managers must understand the dynamic concurrence relationships that constrain the sequencing of tasks as well as the effects of and interactions with resources (such as labor), project scope and targets (such as delivery dates). This paper describes a multiple phase project model which explicitly models process, resources, scope and targets. The model explicitly portrays iteration, four distinct development activities and available work constraints to describe development processes. The model is calibrated to a semiconductor chip development project. Impacts of the dynamics of development process structures on research and practice are discussed.

Keywords: concurrent development, fast track, phased development, iteration, product development, project management, rework, system dynamics

Ford, D.N. and Sterman, J. "Dynamic Modeling of Product Development Processes." System Dynamics Review. 14(1): 31-68. Spring, 1998.

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Impacts of Product Development Process Structure on Cycle Time and Project Manageability

David N. Ford

Concurrent development is frequently used to reduce cycle time. But reducing cycle time often makes projects more difficult to manage. Existing models cannot adequately describe the process drivers of cycle time and manageability. This paper introduces the Internal Precedence Relationship (IPR), an improved tool for modeling concurrence. We use IPR, circular iteration and multiple development activities in a dynamic simulation model to investigate the impacts of process design on cycle time and manageability. Our results expand the concept of tradeoffs between reduced cycle time and manageability and point toward iteration management as a potential tool for achieving both objectives simultaneously.

Ford, D.N. “Impacts of Product Development Process Structure on Cycle Time and Project Manageability”. Proceedings of the Third International Product Development Conference, European Institute for Advanced Studies in Management, Fountainebleau, France. April 13-16, 1996.

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Linking Academic Theory and Industry Practice with Student Interactive Projects

David N. Ford and Richard Paynting

The Bose Corporation and Massachusetts Institute of Technology (MIT) cooperated in an interactive project to apply system dynamics to product development. Bose and MIT participated at four levels: as individuals, as teams, as sponsors, and as organizations. The participants brought different but complementary objectives, perspectives, and abilities to the project. The MIT team consisted of three graduate students in the Applications of System Dynamics course at MIT's Sloan School of Management. Several product developers and managers of Bose's Systems Products Division participated. The teams used Products Division participated. The teams used a tightly coupled combination of facilitated discussions and model building to explore a current product development issue with the system dynamics methodology. The flexibility of the sponsors, teams, and project design allowed adjustments to both projects; inherent ambiguity and an unexpected change in scope. The integration of complementary projects features and participant capabilities ta several levels helped reach the goals of both the Bose and MOIT teams. This paper reports on the project and participant features that linked theory and practice, and introduces a tool to describe and explain the project. A design for interactive projects could improve projects from both industrial and academic perspectives.

Doyle, J. and Ford, D., "Mental Models Concepts Revisited: Some Clarifications and a Reply to Lane," *System Dynamics Review*, Vol. 15, No. 4, pp. 411-416. Winter, 1999.

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