Virtual Teams: The Design of Architecture and Coordination for Realistic Performance and Shared Awareness

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Introduction
Global business, increased supplier involvement, network communications and pressure on travel costs have led to increased use of virtual project teams. In many cases the teams have little previous experience working together and no shared awareness of project assumptions, feasibilities, and risks. Traditional centralized and detailed planning is not an effective option for these projects. While some experts have proposed qualitative or "soft" recommendations for these teams, project managers need a pragmatic way to plan and launch projects with virtual teams. This paper describes the challenge of virtual teams, why traditional approaches do not succeed, and introduces the conclusion of years of research to address this problem. The resulting virtual planning method and tools are demonstrated against the authors’ experiences in industry.

The Challenge of Virtual Teams
In the paper we define a virtual team as a dispersed group of people attempting to behave as if co-located because the work they share is tightly coupled. With this definition a dispersed set of people on the same project is not a virtual team if they have little need to interact. On the other hand, if a group is co-located and their work is tightly coupled they are considered an ordinary team rather than a virtual team.

The presence of virtual teams and need for them is without question. Many authors have addressed this topic over two decades. Binder, in characterizing teams in global projects, describes their purpose as to “unite highly specialized team members in the same project without relocating them...”, yet doing so triggers a “cost to overcome” from such dispersed work. (Binder 2008, p10) While he offers many ways to categorize different types of global work, he does not offer a practical method to forecast that additional “cost to overcome.”

What are the drivers of this additional cost? The most often discussed qualitative driver is culture: "By implication, the traditional model of work meant that everyone in the group of course spoke the same language and took their non-verbal cues from the same broader culture." (Lipnack 1997) Yet beyond a generic notion of cultural differences, characterizing the challenges requires one to dig deeper. The software industry has pursued aggressively the use of global, virtual teams. James Herbsleb is a thought leader through his research on global software development (GSD). Recently he stated that “The fundamental problem of GSD is that many of the mechanisms that function to coordinate the work in a co-located setting are absent or disrupted in a distributed project.” (Herbsleb 2007) He goes on to describe the challenge as communication that is less frequent and less effective, a lack of awareness amongst teams, and inherent incompatibilities in work processes, tools, and culture.

Coordination of teams through information is at the heart of the drivers listed above. A National Institute of Science and Technology study (Gallaher 2004) reports that 40 percent of engineering time in infrastructure projects is spent locating and validating engineering information. Furthermore, the study found that 30 per cent of project costs are wasted due to poor communication between systems leading to a loss of US$15.8 billion annually. The NIST report identified areas where savings, namely reuse of information, can reduce project delivery times up to 50 per cent. Most of the NIST report’s data referred to US based projects. For globally distributed teams working on complex engineering systems the situation can be assumed to be exacerbated.

So the challenge of virtual teams is the coordination through information that traditionally would be either tacit or locally available. Furthermore, Oravec addresses the need to categorize coordination as a type of activity itself (Oravec 1996). She refers to Holt who “states that coordination is the "greatest common denominator" of group activities. He asserts that, despite its importance, coordination is an "odd category" of activity because (1) it has no direct product; (2) it often cannot be performed alone; and (3) much of it is not even performed consciously. Holt argues that since coordination is "odd" in these respects, it receives less than its due share of management's attention (although it consumes a large share of organizational resources) and has not as yet obtained adequate academic and research treatment."
A Framework to Evaluate Virtual Teaming

Over the last 15 years in our industrial work we have been confronted by the need for virtual teams in complex global initiatives, mostly in product systems development (aerospace, machinery) and strategy rollouts. Our concerns have been very pragmatic: to forecast a project’s schedule and cost, making decisions about project architecture and selection of global teams based on these forecasts. Without a very real prediction of the marginal cost and schedule impacts from “going virtual”, one is not able to generate accurate forecasts and make optimal project decisions. In which cases could we assume that dispersed individuals could effectively act as a team, or would a decomposition of the work make more sense? We have found time and time again a common notion that collaboration technology and bandwidth allow a virtual team to perform as if co-located (or better), yet evidence shows this notion to be a naïve myth.

As we considered these questions we have learned to quantify the coordination across and within teams. We began to see that increased coordination not only changes the burden on teams in a project, it changes their roles and responsibilities. Going virtual drives changes in standard work processes and skills requirements in the enterprise. Our approach therefore became not only quantification of coordination, but also consideration of the overall architecture of projects taking these virtual options into account.

Attempts to Mitigate Virtual Team Risks

When faced with virtual teams, planners have attempted to reduce the differences between virtual and co-located teams with increased interface definition, process automation, and collaborative communication tools. These three techniques can improve efficiency and reduce risk, yet it may be misleading to believe that work can be performed by any virtual team if these techniques are in place.

1. Interface Definition: By clarifying interfaces that fall within the virtual team, the need for interaction may decrease. However, artificially adding interfaces to work that is naturally coupled may delay, but not remove, the demand for the team members to interact. In these cases downstream rework becomes much greater while apparent upstream progress is misleading.

2. Process Automation: Similarly, defining a fixed process and automating the sequence of interactions within the team may be beneficial. However, if the work could be automated with little need for learning, agility or change, this would imply that the work is not inherently coupled. If so, why assign a virtual team? Two separate teams might do just fine.

3. Collaborative Communication: Network based collaboration platforms are popular, both structured and self-organizing. For interactions that fit well with I.T. exchange, these tools offer great opportunity to support interactions at lower cost. To a limit. At some point quality, flexibility, and shared awareness within a team on work that is uncertain and dynamic is needed. No virtual team without shared previous experience would be as effective as a co-located team already at high performance.

These techniques improve efficiency, yet does it makes sense for a virtual team to be allocated in the first place? Is the nature of the work being assigned suitable to virtual teams? Do the individuals assigned have shared work culture and coordination skills suited to the work at hand? In the end, a realistic forecast of cost, duration, and quality for the project with a virtual team must be compared to other options for allocating the work. Our framework for considering the feasible and optimal architectures for virtual teams must evaluate the value, amount, and difficulty of coordination activity.

In many cases the need to use dispersed individuals is not a choice. A unique combination of skills, different interests, and variation in labor costs can drive dispersed participation. Often companies ignore or overly simplify the risks and costs of coordination. Direct, short term savings are visible (e.g. labor arbitrage), yet coordination costs and long term competence impacts are hidden. An analytic exercise comparing scenarios (with and without going virtual) pushes one to consider the opportunities and risks -- where, when, and why -- of virtual teaming.

Research Results: Activity Models to Predict Coordination

Qualitative recommendations for better performance by dispersed teams abound, but these are not sufficient. In 1994, based on experiences in planning and managing global product development, a team was formed at the University of Tokyo, M.I.T., and University of Connecticut to improve the performance of global work. The
research established visual models and simulations of project activity by global teams. (Moser 1997, Moser 1998). Our approach to consider and manage virtual teams is based on the insights of that original work.

Consideration of a team’s capacity to coordinate should begin early, when decisions about project structure are being made. A project as total activity includes the interplay of several architectures: product (PBS), work (WBS), and organization (OBS) architectures. The position of a team within a project and the demands on their attention (including coordination) is determined by how these three architectures overlap. For a virtual team we must examine the demands that will fall within the team and their ability and capacity to satisfy those demands.

Our research led us to four key points:

1. Coordination is real activity
2. Coordination can be predicted
3. Coordination should be budgeted, allocated, and measured
4. Tacit coordination abilities are an asset

Coordination is real activity

Coordination – the management of dependencies – has been shown by research and experience to be a significant portion of a modern project’s activity. As projects become more complex and teams fall increasingly across more significant dependencies, coordination can require half or more of the total effort. Insufficient coordination impacts quality. Over coordination creates waste. For virtual teams the demand to coordinate within the team can be surprising, especially if expectations for effort and duration have been set by experience inconsistent with the project at hand.

Coordination can be predicted

We predict the amount of coordination as a product of the demand for interaction (coordination dependence) and the supply of interaction (coordination distance). (Moser 1997)

Coordination = Dependence X Distance

Dependence is well understood from existing techniques so will not be discussed in this paper. Distance, the ability of two teams to coordinate – is not yet in common use. It is significant that coordination distance is not determined by a single individual or team’s skills.

A team may be at a small distance when interacting with a local, familiar team, and yet (even for the same work) suddenly have a very high coordination distance with others.

Coordination = Dependence X Distance can be evaluated both at aggregate and granular levels. Overall, how “distant” are the teams (or individuals in a virtual team)? Is the work to which they are allocated highly dependent?
At a granular level we can ask very specifically how the nature of the work, the skills of the workers, and the architecture of the project lead to an increase or decrease in expected coordination effort. In more sophisticated behavior-based simulations, coordination is predicted from a market-like interaction of dependence and distance.

We have seen from hundreds of projects that this fundamental equation allows us to predict the degree and placement of coordination. By predicting coordination we have been able to uncover root causes of unexpected project duration, progress (S curves), and quality issues (rework, propagating delays).

**Coordination should be budgeted, allocated, and measured**

With an ability to predict coordination as a real activity, the next step is to ensure teams have the awareness, priorities, and resources to effectively complete coordination at the right time and with the relevant individuals and teams. Time and attention set aside to coordinate with others at the wrong time (before sufficient progress, without information which is to be exchanged, or too late for informed decisions to be made) becomes waste, lowering productivity and preventing coordination at a time earlier or later when it would have mattered most.

Gantt charts and other project plan representations do not show coordination. Traditionally individuals anticipate coordination based on experience or “gut feeling”, assuming that others with whom they need to coordinate will be available and share priorities when the time is right. In contrast, our method builds the allocation of coordination activity into project plans from the start. During execution, allocated coordination effort is monitored and the satisfaction of dependencies measured.

**Tacit coordination abilities are an asset**

Virtual teams require time and learning to reduce internal coordination distances and thus improve performance. These coordination skills, tuned to the nature of dependencies and distances at hand, evolve at the pace of organizational learning. For unique demands that arise each project it may be difficult to significantly reduce coordination distances within the short timeframe of the project. Instead, by viewing short coordination distances ("coordination proximity") as an asset, we can consider placing teams across the project architecture to take advantage of existing coordination skills.

**Project Design: Selecting a Project Architecture including Virtual Teaming**

We have integrated the forecast of coordination within and across teams in a method used for early life-cycle planning called Project Design. In the same way that complex products are designed through modeling, prototyping, and trade-off, a project’s total architecture and activity can be designed, taking options into account including virtual teaming.

By forecasting coordination in a project before starting, teams begin to see a pattern of when and where coordination is most valuable. Likewise they see where and when interaction has less value or even creates waste. Not all dependencies are equivalent; the value of interaction by teams (across the dependencies) will shift depending on the nature of the work and the nature of the teams. More “distant” teams collaborating across stronger dependencies will require very much coordination. In the diagram to the left, Teams 1 and 2 (T1 and T2) are both highly distant and highly dependent. It follows that since dependence also changes during the project lifecycle, the demand and value of coordination also shifts.

The Project Design approach has been used successfully over the last decade in hundreds of projects. The approach is both analytically accurate and compelling to participants as a collaborative learning experience. In brief summary, the Project Design approach follows a simple set of steps:

1. **Visually model activities** and how they relate to project architectures (PBS, WBS, and OBS).
2. **Capture metrics and FTE effort** for activities, separate from coordination effort which will be derived.

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Originally published in PMI 2009 Global Congress Proceedings
3. Establish *dependencies* across activities, including *concurrent* and *mutual* dependence (not just discrete temporal relations such as Finish to Start).

4. Establish *coordination distances* for teams, a relative measure compared to the nominal, co-located case.

5. Determine how overlapping project architectures lead to team *distances across dependencies*.

6. Calculate *coordination* activity for each dependency as a product of dependence and distance.

7. **Budget, Allocate, and Manage** coordination as real activity. Include in overall schedule forecast.

Both during early planning and downstream as situations change, teams iteratively design and re-design their project. In hours rather than days (or weeks) the teams examine multiple, accurate scenario forecasts, thinking together on how best to proceed. As Larry Bucciarelli pointed out in his observation of development teams, "Design by its very nature, is an uncertain and creative process. In every design task there is an opportunity for creative work, for venturing into the unknown with a variation untried before, and for challenging a constraint or assumption, pushing to see if it really matters." (Bucciarelli 1994) The *Project Design* approach brings this creative, challenging, and collaborative practice to strategic project planning.

**Case Study**

A global manufacturer launched a new product family for four global markets. This product series is significant in the company. At the same time they were moving towards global engineering centers and use of virtual teams on key, early design activities. The original plans showed the standard work with five gateways (G1 through G5), related services, divergent local requirements, an emerging supply chain, and rollout across regional markets.

After the project completed -- years later than originally predicted -- the executives asked “What should we have been able to see at the first gateway, using the knowledge we had at that time?” We applied the *Project Design* method and TeamPort visual modeling tools to answer this question. Uncovering coordination activity was the key to this analysis.

**Three scope scenarios**

Based only on information available early in the project, three different project scope scenarios were modeled: (1) the original scope, (2) original scope and regional options, and (3) a scope increase after a design gateway. These three scenarios were modeled in TeamPort. Project forecasts were simulated including coordination (using our GPD method). For comparison, we also simulated these three scenarios without consideration of coordination and other factors (CPM).

**CPM** refers to the *Critical Path Method* as used in traditional project tools. It ignores communication, time zones, mutual dependence, re-work, and other global factors. **GPD** refers to analysis by GPD’s *TeamPort* Project Design software which incorporates communication, complex concurrency, re-work, time-zones and other factors.

**Forecasts of coordination generated by TeamPort**

The forecasts of both cost and timing of the G4 milestone across the three scenarios are shown in the figure to the right. The three scenarios predicted using CPM are millions of dollars and 15 to 24 months short of the actual date. The GPD forecasts show both cost and duration accuracy, with the full scope (original + options + increase) within 2 months and $200k of actual.

The forecasts by the project manager at each gateway as the project proceeded are also shown (@G1, @G2…). Clearly, even as project reality unfolded with significant difference from the baseline, the PM’s estimates were heavily influenced by the original CPM plan.
Accuracy can also be seen by comparing the forecasts of gateway timing shown in the figure below. Across scenarios and methods of forecasting, the final G5 gateway date varies by up to 3 years. However, the actual dates are most tightly corresponding to the GPD simulations for the full scope third scenario.

In summary, it was possible to predict within 5% the cost and schedule before the first gateway, including coordination. As full scope became apparent prior to G3, a re-designed forecast was possible, years before G5. In that case, measures to change architecture, resources, and/or scope could have prevented the project from failing.

**Project Design Principles for Virtual Teams**

With method and tools for designing a project including coordination, one can compare project plan scenarios that include (or do not) virtual teams. High-level architectural changes are considered to design a better project. Some of the project characteristics that can be changed include:

- **Do-Nothing: Ignore Coordination**: Implies that communication is instantaneous, all teams are co-located with common language, and low coordination doesn’t cause quality problems and rework.
- **Change Team Role Allocation**: assign less distant teams to share the strongest dependencies
- **Move Dependencies**: Change interfaces so that dependencies fall across different parts of the project architecture
- **Reduce Coordination Distances**: transfer individuals, shift work times, or hire multi-lingual team members who can make an impact by reducing distances within the time frame of the project
- **Automate Coordination for Efficiency**: the exchange of knowledge across dependencies is aided by a technical solution, in some cases avoiding the need for interaction amongst teams

**Conclusion**

There is no virtual team which makes sense to deploy always. Instead, the particular make-up and placement of a virtual team determines its potential value. The nature of work and dependencies in each project create a demand for interaction. This coordination demand must be examined as it falls across the project architecture and thus across team coordination distances.

Based on *Project Design* one can make choices – to design – the most appropriate and valuable use of virtual teams for the architecture at hand. Our experience over a decade and hundreds of projects has shown:
- **Coordination** – interaction to satisfy dependencies – can lead to **35% and greater of the total** effort, cost, and duration of projects.

- Choosing the best **coordination architecture can lead to typically 20%** improvement in time/cost performance.

A virtual team, as implied by the word “virtual”, is not the same as a co-located team. We must decide what is essential about this team’s shared activity, and if benefits of performance (since they are not co-located) are worth the costs and risks.

**References**


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