Why is the System Anatomy Useful in System Development?

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Images such as Gantt, WBS, PERT, and CPM have always played important roles in project management. In recent years, new types of images, such as the system anatomy, have emerged in complex development projects. The purpose of this chapter is to investigate why alternative images seem to be more useful than the traditional ones in turbulent and complex circumstances. In conclusion, we find that the alternative images are focused on integration activities and critical dependencies in the project. Typically, they emphasize common understanding and comprehensibility over formalism and rigor. In addition, these alternative images seem to be resonant with how our cognitive apparatus conceives coordination, thus making them more apt for managing complex development tasks.[1]

Introduction

Projects are most often described in terms of plans, resources, tools, organizations, etc. In essence, project management (PM) is about enabling all these things to jointly contribute to the project objectives within given financial and time limits. Today, organizations are facing ever-increasing complexity and turbulence. One way to manage this situation is to use images for coordination and communication; images such as Gantt charts, PERT (Program Evaluation and Review Technique) / CPM (Critical Path Method) charts, WBS (Work Breakdown Structure). These "traditional" images were developed many years ago, and are still useful in many cases. However, it has been reported that they can become almost unmanageable in projects with many changes (Maylor, 2002; Milosevic, 2003).

[1] This chapter is a revised version of the paper Taxén, L., & Lilliesköld, J. (2008). Images as action instruments in complex projects, *International Journal of Project Management*, *26*(5), 527-36. Reprinted with permission from Elsevier.

The system anatomy and its related images are examples of alternative images that have been found useful in practice for managing complex system development tasks. The purpose of this chapter is to investigate which qualities these alternative images have, and why traditional images appear to be insufficient in complex circumstances. As a theoretical "screening grid" for the investigation, we will utilize a particular framework called the Activity Domain Theory (ADT). This theory emerged in the telecom practice at Ericsson, a world-wide supplier of telecommunication products, as a way to understand the coordination of extraordinary complex development projects (Taxén, 2009).

The chapter is outlined as follows. First, we briefly describe traditional and alternative images. Thereafter, we provide a short overview of the ADT, the "search light" by which we then investigate these images. In conclusion, we find that the alternative images are means for managing integration activities and critical dependencies in a project. Typically, they emphasize common understanding and comprehensibility over formalism and rigor. In addition, the alternative images seem to be resonant with how our cognitive apparatus conceives of acting in a coordinated way. For this reason, alternative images might be better suited to managing complex development tasks than traditional ones. We suggest that future research into the management of complex projects needs to take these findings into account.

Traditional Images

The dominant methods and images (WBS, Gantt, PERT, and CPM) for planning a project were developed in the late 1950s. These images show graphically the sequence of, and the relationships among, the individual work tasks required for the completion of a project.

The Work Breakdown Structure

A WBS is often performed as the first step in the planning process. It is a deliverable, oriented grouping of project elements that organize and define the total scope of the project (work not included in the WBS is outside of the scope). By breaking the work down into smaller elements, it is believed that risks and uncertainties will be reduced, since each level provides a greater probability that every activity will be accounted for. In its graphic format, it is obvious why the WBS is often described as a project family tree, hierarchically displaying interim and end project deliverables (see Figure 12.1):

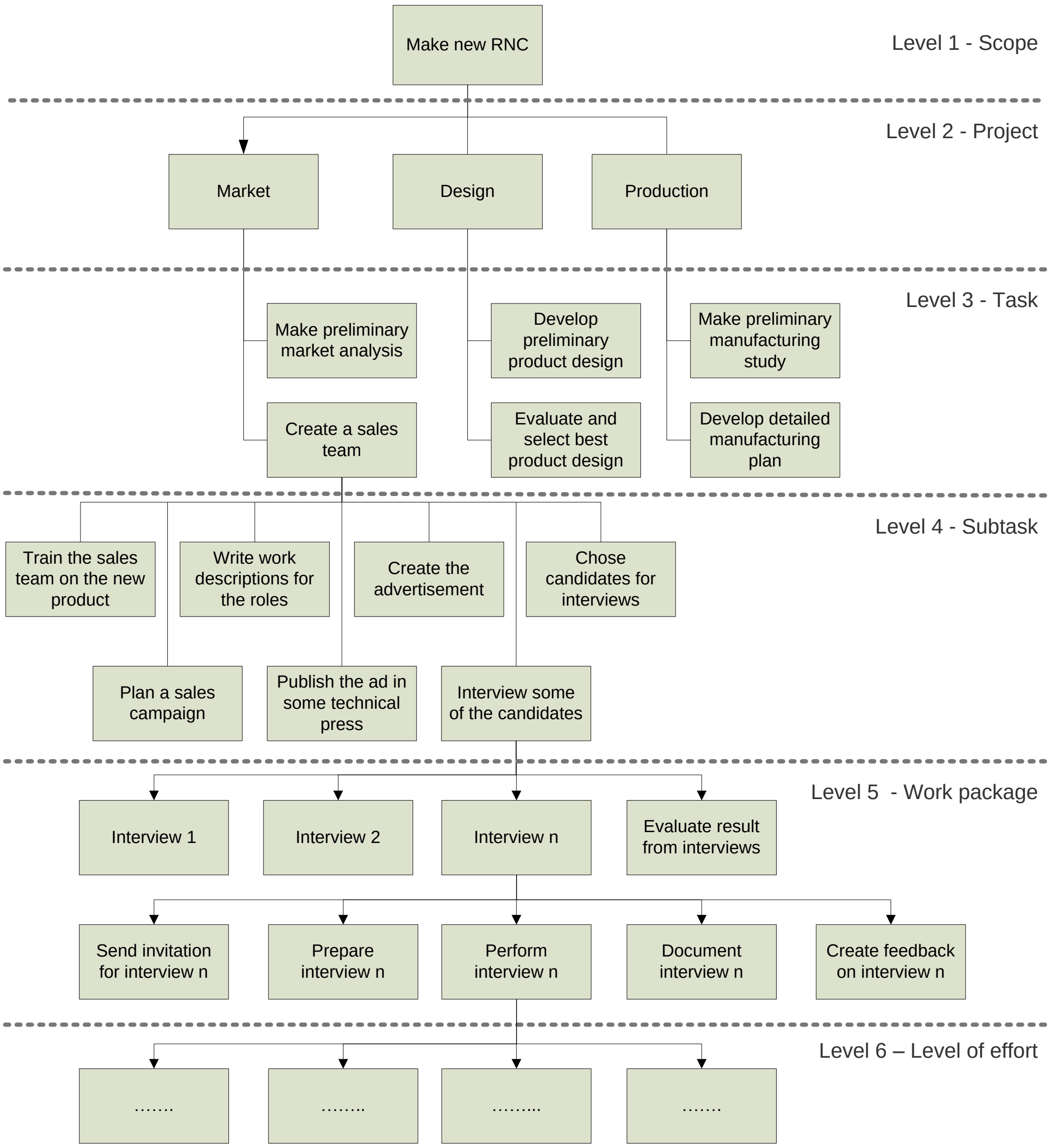

Figure 12.1: A WBS diagram

Although a variety of WBS forms exist, the most common, according to Kerzner (2001), is a six-level indented structure. The top three levels are called the Managerial levels: 1) Total Program/Project, 2) Project/Subproject, and 3) Task. The three lower levels are referred to as Technical levels: 4) Subtask, 5) Work Package, and 6) Level of Effort. Project managers normally manage and provide status reports for the top three levels (ibid.).

Gantt

Even though this is the oldest formal scheduling tool, it is still widely used. The Gantt chart uses bars to represent activities or tasks (see Figure 12.2). It shows when the project and the activities start and end against a horizontal timescale. The chart is a useful tool for planning and scheduling projects, as well as for monitoring the progress of a project.

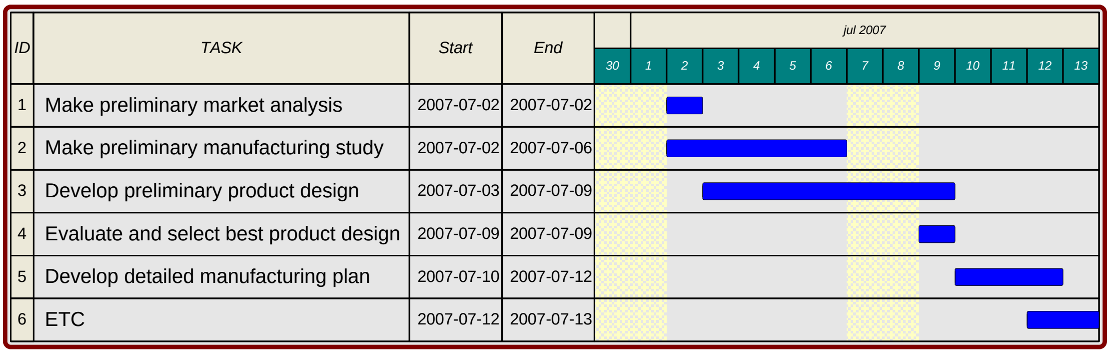

Figure 12.2: A typical Gantt chart

Network Diagrams

A network diagram represents project activities as nodes or arrows, determining which of them are critical in their impact on project completion. CPM is one of the more common network diagram techniques for analyzing, planning, and scheduling projects. CPM is similar to another common network diagram technique called PERT (see the example in Figure 12.3). The difference is that activity duration estimation is deterministic in CPM, while PERT uses a weighted average to calculate the expected time of activity duration.

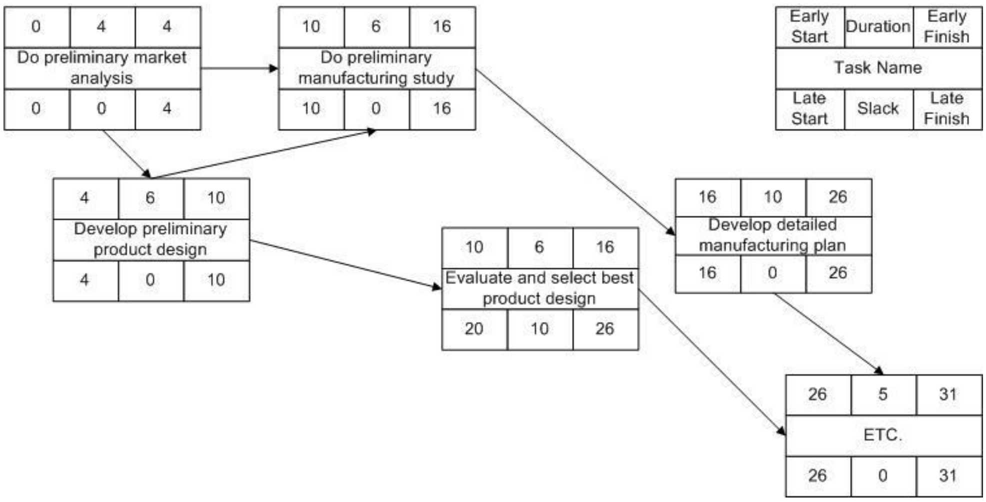

Figure 12.3: A PERT diagram

A driving force behind developing a network diagram is its usefulness in highlighting interdependencies among activities. Initially, this was also the major discrepancy between Gantt charts and network diagrams. This divergence has, however, disappeared over time, since Gantt charts have incorporated inter-activity dependencies. Just like the Gantt chart, all major

PM software tools provide CPM/PERT chart notations. And just as with Gantt, CPM/PERT charts exist in several versions, allowing for different modeling possibilities.

Except for the layout, the main difference between CPM and the Gantt chart is that CPM states time relatively. Moreover, tasks are equipped with information pertaining not only to duration, but also with early and late start and finish (relative) times. Furthermore, slack time, i.e., the time span of independency, is expressed for every task. Slack time, in turn, facilitates the identification of the project's critical path.

Alternative Images

The alternative images we are interested in here are the *system anatomy*, the *organic integration plan*, and the *development plan*. The "system anatomy" is the same as described in Chapter 2. The "organic integration plan" and the "development plan" represent images related to the system anatomy, the purposes of which are described in the following.

The first image (see Figure 12.4) is an example of a system anatomy. The purpose of the anatomy is to illustrate the common understanding among system experts about how the system works of in terms of *capabilities* and their *dependencies* (and independencies). Critical capabilities can be easily recognized, such as the encircled capability "Start-up" in Figure 12.4.

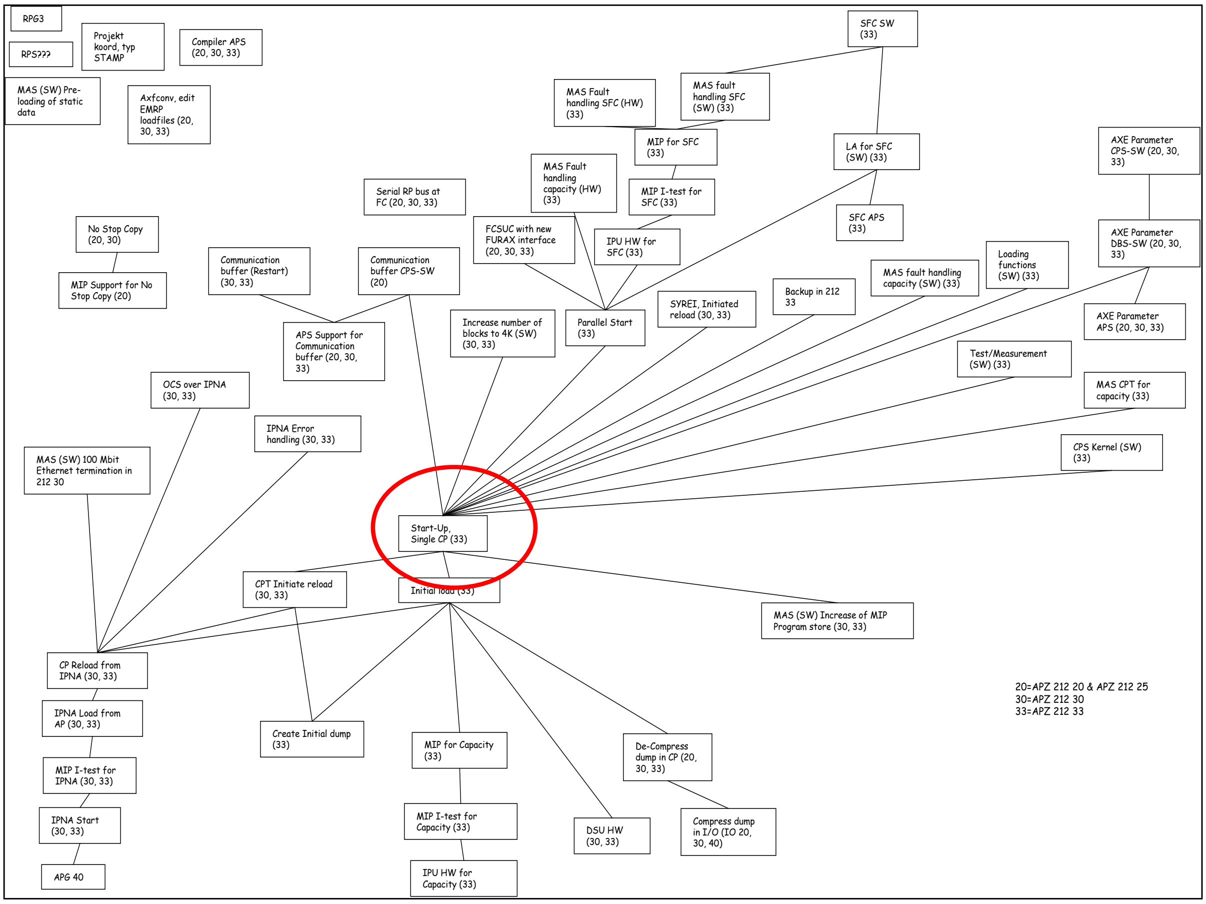

Figure 12.4: The system anatomy of a processor

The second image, the organic integration plan, illustrates the grouping of capabilities into suitable integration and verification packages (see Figure 12.5). These packages correspond roughly to the work packages (Level 5 in Figure 12.1) in a traditional WBS. As can be seen, the anatomy is a prerequisite for doing the organic integration plan.

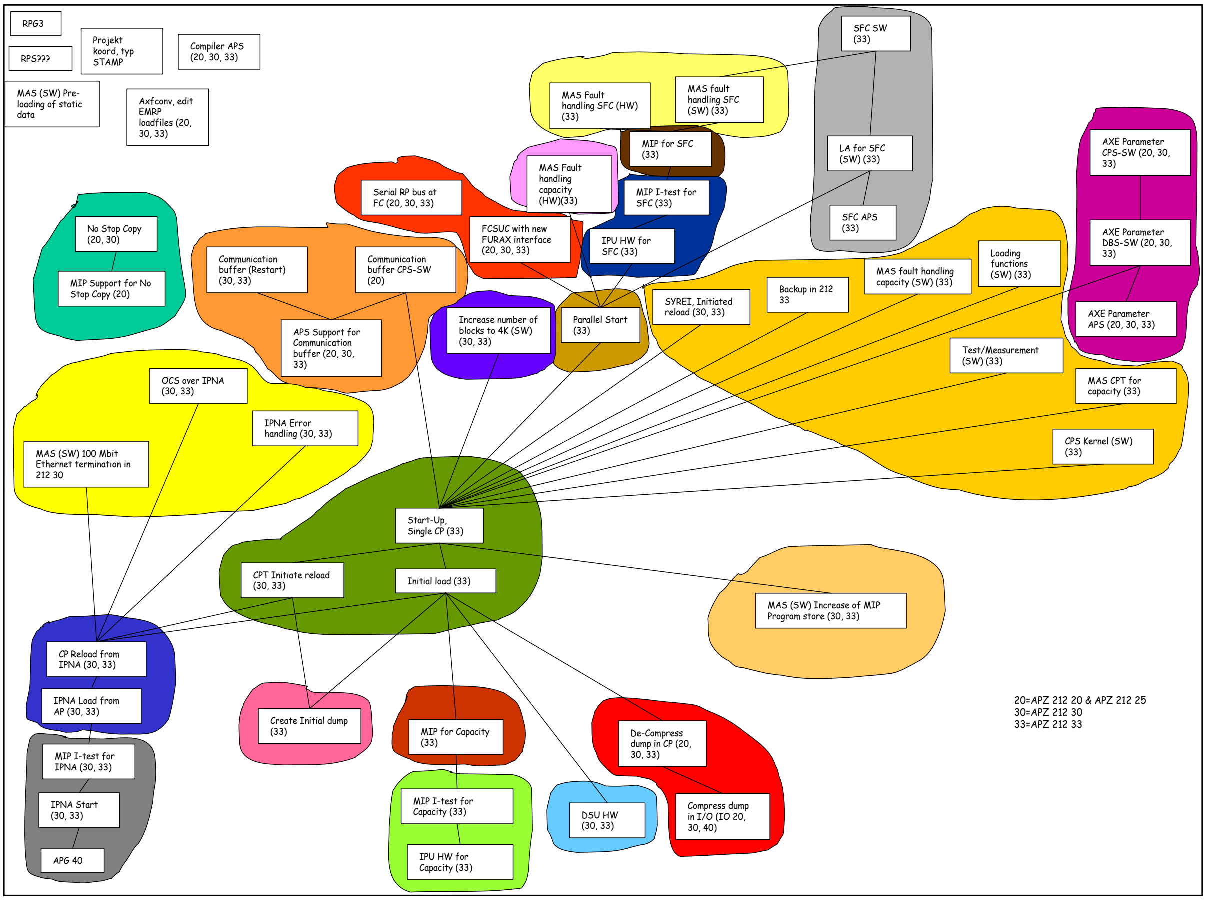

Figure 12.5: An organic integration plan for the development of a processor

When defining the organic integration plan, design and testing are parallelized as much as possible. The plan describes in what order work packages need to be completed to ensure smooth progress. The structure of the plan is determined by a number of circumstances such as the system architecture, available resources, customer feedback, complexity of functions, geographical proximity between resources, joint functions testing, and so on.

The system anatomy and the organic integration plan are the main images used to manage the project. Sometimes, however, a third type of image called the development plan has been used (see Figure 12.6). In this image, which resembles network diagrams such as PERT or CPM, the focus is on what is delivered when, and from whom. When the development plan is created, resources are assigned and dates for deliveries of the increments settled. For each work package, traditional time and resource plans are made as well. The development plan also clarifies the receiver of each internal delivery. Thus, it focuses on the dependencies between subprojects. In Figure 12.6, such a plan for the processor is shown. It can be seen that this plan is a ‘tilted’ variant of the organic integration plan, where the timing aspects are emphasized.

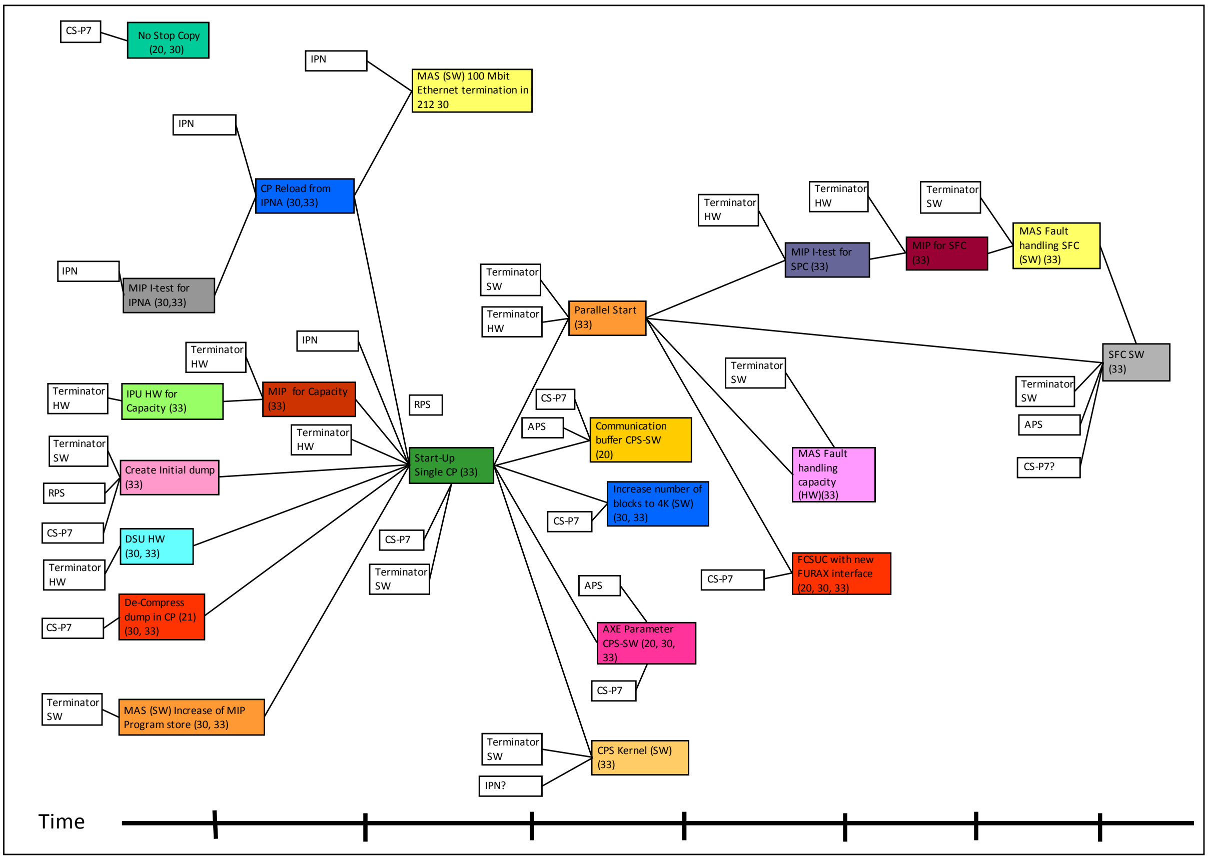

Figure 12.6: A development plan for the processor project

The dependencies in the development plan between subprojects clearly show the impact of a delay in the project, since all the internal deliveries are in some way related to the delivery of the final system to the customer. Thus, the plan provides the project with early warnings of delays and gives the project manager ample time to take corrective actions. On the surface, the development plan appears to be similar to a CPM-diagram. However, the development plan and the CPM-diagram are derived in completely different ways.

The Activity Domain Theory – A Theoretical “Search Light”

When trying to understand complex situations, there is a need for some kind of framework or perspective from which relevant things can be distinguished out of the myriad of details that otherwise stand out as an incomprehensible mess. Such “search lights” are called, by a more sophisticated name, “theories”. In this chapter, we will use a specific theory called the Activity Domain Theory (Taxén, 2009). The central concept in this theory is the *activity domain*, which simply is a convenient name for capturing fundamental aspects of how humans coordinate their actions.

In order to illustrate the activity domain, we may use the mammoth hunt scenario in Figure 12.7:

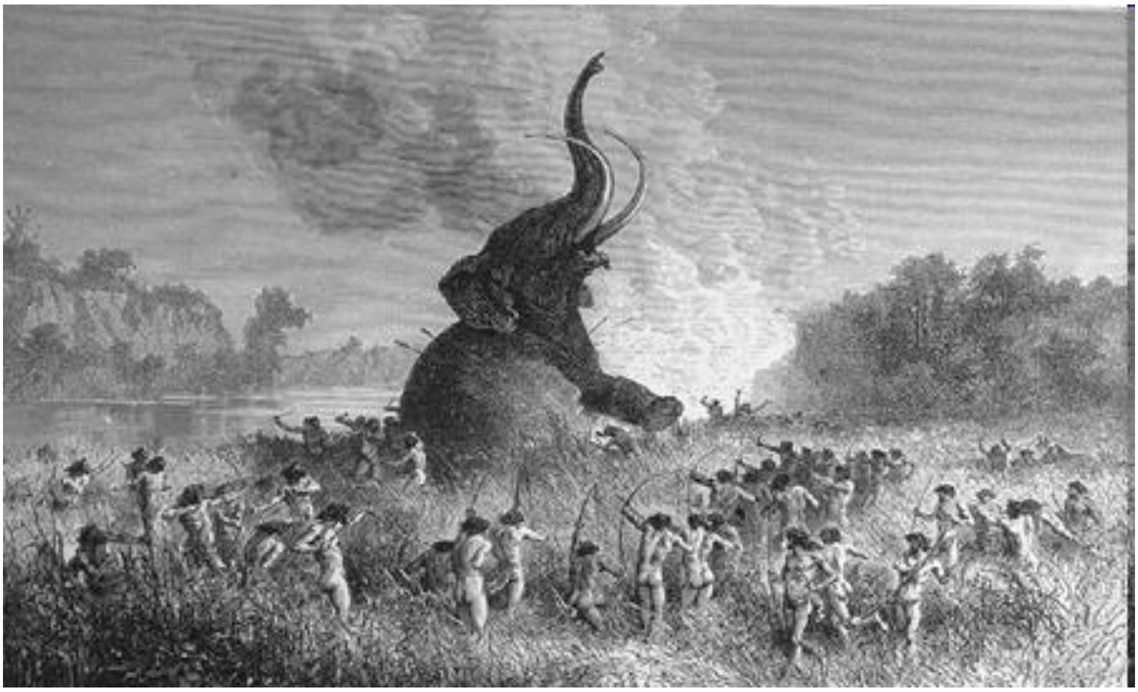

Figure 12.7: Illustration of an activity domain (Bryant & Gay, 1883. Original wood engraving by E. Bayard).

When looking at this scene some things immediately come to mind. The mammoth is clearly the *object* in focus for actions. There are also several perceivable *motives* for the hunt, the primary one presumably being obtaining food. Related motives may be obtaining material for clothing, making arrowheads, and the like. Together, the object and the motive form a point of gravity around which everything else revolves: hunters, bows, arrows, actions, shouts, gestures, and so on. Moreover, it is obvious that the hunters have to act in a coordinated way; if every hunter attacked the mammoth one at a time, the result would be disastrous.

In order for hunters to coordinate their actions, certain capabilities are needed. To begin with, there must be a common understanding about the context around the mammoth. This context frames the relevance of individual actions. For example, it can be seen in the background of the illustration that some hunters, the beaters, have started a fire and are making noise to scare the quarry away. The mammoth escapes in a direction where other hunters wait to circumvent the quarry and kill it. However, it is only in the light of the activity domain as a whole that the beaters' actions of scaring the quarry away make sense.

Second, a common sense of what things are relevant in the context must be developed. This enables the actors to orient themselves in the same way that a map does. For example, the river is probably relevant since it hinders the mammoth from escaping in that direction. On the other hand, the fish in the river are certainly irrelevant in this activity domain (they are of course relevant in a fishing activity domain).

Third, when the hunt starts, individual actions must be carried out in a certain order that enables the actors to synchronize their actions. For example, the hunters must be in place before the beaters start making noise, the archers must shoot their arrows at a certain command, and so on.

Fourth, the archers cannot shoot their arrows in any manner they like. If they shoot in the wrong direction, other hunters may be hit rather than the mammoth. Gradually, after many successful and less successful mammoth hunts, a common understanding about how to achieve appropriate mammoth hunting will evolve. This provides a common understanding of the “taken for granted”: rules and norms indicating proper patterns of action that need not be questioned as long as they work.

Fifth, activity domains are not isolated. The brought-down quarry will be cut into pieces and prepared for eating. This is done in a cooking activity, which in turn has its own particular motivation (to still hunger) and object (which happens to be the same as that for the hunting activity: the mammoth). Other related activities might be manufacturing weapons and weapon parts from the bones and the tusks of the mammoth. So, when several activity domains interact, certain issues must be resolved in the transition between activities, such as how to share the quarry among hunters and cooks, or deciding how many ready-made arrowheads will be returned for a certain amount of food. Thus, there must be a common understanding about how to coordinate different activity domains.

These five aspects of coordinating actions are called *activity modalities*, and represent inherent predispositions for acting in the world. The term “activity modalities” is deliberately coined to connote with *sensory modalities* such as vision, hearing, touch, taste, smell, etc. Thus, the way we experience the world through our senses is transformed by our brains into an activity modality percept that enables acting as individuals and together with others (Taxén, n.d.).

In summary, the activity domain is characterized by the following aspects:

- The actions in the domain are *motivated* by some need, and directed towards an *object*.
- The object and motive impel the formation of a context in which actions make sense (*contextualization*).
- Actions require a spatial comprehension of the context (*spatialization*).
- Actions are carried out in a certain order (*temporalization*)
- Actions require rules, norms, etc. that express which actions are valid in the domain (*stabilization*)
- Specialization of actions according to different motives and objects brings about a need to coordinate domains (*transition*)

An inherent part of an activity domain is that actions are always *mediated* by tools or means. The hunters make use of bows and arrows, the beaters use some kind of tools to make a fire, the assault on the mammoth is most certainly coordinated by gestures and shouts, and so on. The individual actors must, of course, learn how to use such means, both tools and specific mammoth-hunting terms, in order to become resources in the mammoth hunting activity.

Discussion

In this section we will use the theoretical “search lights” provided by the ADT to investigate the properties of traditional and alternative images. We begin with the traditional ones.

Traditional Images

The primary purpose of traditional images is to control planned actions and, in addition, to optimize time and effort. These images were not devised to support tasks such as creating a common understanding of the work, supporting the project’s alignment of itself with moving targets and emerging, fuzzy goals, and making decisions regarding changes. Such actions were to be done by one or a few key persons responsible for the work.

A first observation of traditional images is that none of them provide a clear and coherent view of the system to be developed. The focus is on activities. The system being developed is visible only indirectly as texts in the boxes, for example, “Develop *manufacturing plan*” and “Develop preliminary *product* design”. Nor are the dependencies between system elements shown. Such dependencies, which indeed constrain freedom in laying out the order of activities, must thus be kept implicit in the minds of the main actors. It’s like a mammoth hunting “project”, in which the hunters would see only vague fragments of the mammoth like the tail, the tusks, the trunk, and so on, without ever catching a view of the entire mammoth. In particular, vital dependencies might remain concealed in a project, something that quite naturally may have severe consequences.

Next, in both Gantt and network diagrams, there is a strong temporal emphasis, as is indicated by the horizontal time axis. Therefore, temporalization modality is dominant in these diagrams. Concerning WBS images, these appear to display several activity modalities in one image (see Figure 12.1). At the very top, the object of the activity is given: “Make new RNC”. At Level 2, the boxes seem to signify contexts of work division: “Market”, “Design”, and “Production”. These contexts can be seen as activity domains. However, there is no indication of how these domains depend on each other. At Levels 3 to 5 there are clear indications of a sequences of activities; that is, a temporal dimension.

Therefore, from an activity modality point of view, several modalities are, so to speak, compressed into the same two-dimensional WBS image. This makes WBS images hard to apprehend for the human intellect. In more complex situations, this may severely aggravate the achievement of common understanding about a project.

The inclusion of activity dependencies in Gantt diagrams is one indication of increased attention of the importance of dependencies; this is still done, however, within only one modality: temporalization. In addition, several other drawbacks of traditional images have been reported. Network plans look convoluted and perplexing to first-time users. Even though they have a strong temporal character, most network diagrams do not have a time-scale, and appear timeless to the untrained eye.

With respect to changes, Gantt chart and network plans easily become too complex. In fact, it has been reported that updating and maintaining network plans and Gantt charts can be overwhelming for very dynamic projects (Kerzner, 2001; Maylor, 2002; Milosevic, 2003). If the diagrams become larger than one page, they are not useful for communication or discussions. The diagrams are good for static environments, but less useful during constantly-changing circumstances.

In summary, it seems that traditional images either show one modality at a time or squeeze several modalities into the same image, without indicating how these modalities are related to each other. This aggravates the task of forming a coherent perception that makes coordinated actions possible. If the modalities do indeed reflect inherent, cognitive predispositions for acting in the world, then traditional images are weak at mediating such actions.

Alternative Images

The most striking observation about alternative images is that they start from a comprehensible view of the work object in the shape of a system anatomy. Even if everybody does not agree on all the details, there is no doubt about what the target of a project looks like. In a metaphorical sense, the “prey has come out of the fog” so to speak.

Moreover, each image appears to be aligned with a dominant activity modality. The system anatomy has a spatial structure since only static dependencies between capabilities in the system are shown. The organic integration plan shows the dependencies among work packages / activity domains. Hence, in the organic integration plan the transition modality is in focus, visible where the domains interact (see Figure 12.8). This kind of information is absent in a WBS diagram.

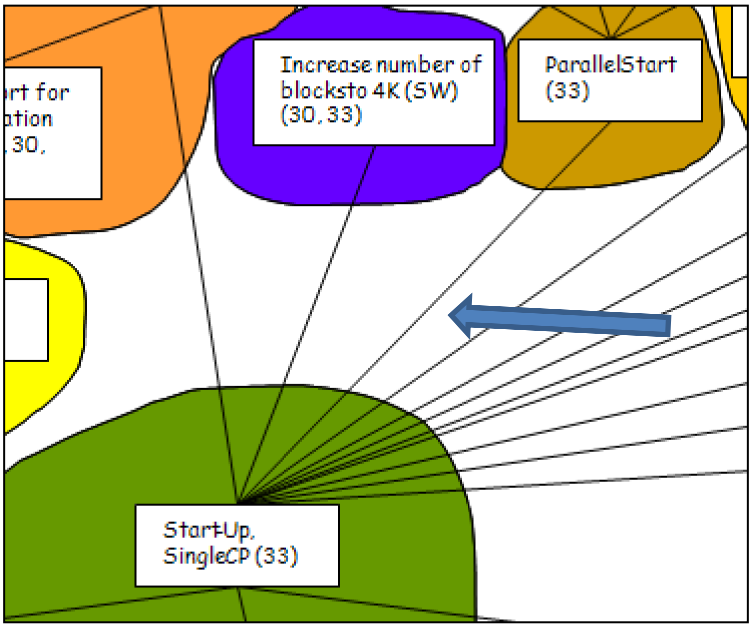

Figure 12.8: Dependencies between activity domains

The development plan has an obvious temporal characteristic since there is a horizontal time axis in the image. Finally, the three images are related to each other through the anatomy. Thus, the dependencies between modalities are clearly seen.

Summary

In summary, we can state the following:

- The system anatomy provides a clear picture of the system to be developed, regardless of whether the capabilities are ultimately implemented in software, hardware, or any other way, for example, by human intervention. In contrast, in traditional images the system is visible only in a fragmented and diffused way.
- Traditional images are focused on optimization and control rather than action and coordination, while alternative images are focused on dependencies and integrations, emphasizing comprehensibility and informality over formality and rigor.
- Both the WBS and the organic integration plan use the “work package” as the unit for planning and monitoring projects. The purpose is to arrive at a reliable estimation of the work effort and to assign suitable units of work that may be distributed to project teams. However, the ways in which the work packages are derived are quite different. The organic integration plan is based on dependencies among capabilities in the system to be developed. This is lacking in the traditional WBS diagram.

- The alternative images each addresses / emphasizes a particular activity modality. Therefore, they must be seen as complementing each other; using just one of them would not make sense.
- A conspicuous difference between traditional and alternative images is that traditional images seem to “compress” different modalities into a single image. However, since these are shown in the same image, it can be expected that the “cognitive load” of making sense of these images increases with increasing complexity. The alternative images, on the other hand, appear to “decompress” the modalities in such a way that each image displays a dominant modality without losing interdependencies with other modalities. It is as if alternative images are more aligned with the modalities than are traditional ones. This would indicate that the alternative images are more resonant with our innate predispositions for acting in the world.

An extensive inventory of the PM literature by Pollack (2007) indicates that there is a shift in PM from a “hard” paradigm to a “soft” one. The hard paradigm denotes a focus on stability, predefined goals, control, reductionist techniques, and the project manager as the “expert”. Up to now this has been the paradigm prevalent in PM. However, more and more evidence is being gathered that points toward the conclusion that the hard paradigm cannot cope with turbulent environments, unstable conditions, moving targets, learning ‘on-the-spot’, and so on.

The alternative images resonate well with a “soft” paradigm. They are used as tools for anticipating possible actions and foreseeing the consequences of these actions. The system anatomy is, in fact, the central coordinating instrument in enormously complex projects. This action aspect of traditional images is much less evident.

An indication of how to approach a softer paradigm is given by the ability of the alternative images to cater to what might be called “federative control” or self-organizing teams, which allow the total project manager to coordinate only what is necessary. At Ericsson, where the anatomy concept has been used, it has been possible to move from a traditional PM approach to a more self-organized approach (Taxén, 2006). Therefore, alternative images may provide one set of instruments for advancing the shift from the hard paradigm to the soft one.

Conclusions

We have investigated the striking observation that extremely complex projects are coordinated and monitored using, in principle, very simple images. In dynamic environments, there is a need to focus on common understanding and dependencies. Images are one way to achieve this. However, it appears that traditional images are not adequate for this purpose. The system anatomy and its related images, the organic integration plan and the development plan, are quite distinct from the traditional ones.

The main reason for their usability in complex situations appears to be that they are better aligned with our innate predispositions for coordinating actions.

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