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Abstract
Images such as Gantt, WBS, PERT, and CPM have always played an important role in project management. In recent years, new types of images have emerged in complex development projects. The purpose of this paper is to make an inquiry into how project management activities are supported by these alternative images, and suggest reasons why the more traditional images appear to be inadequate during turbulent and complex circumstances. In conclusion, we find that the alternative images are a means to managing integration activities and critical dependencies in a project. Typically, they emphasize common understanding and comprehensibility over formalism and rigour. These alternative images seem to be resonant with how our mental cognitive apparatus conceives coordination, thus making it easier to manage complex development tasks.

Keywords: Coordination, Complex development projects, images

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 project objectives within given financial and time limits. Today, organizations are facing an accelerating increase of the complexities they need to manage. For example, the speed of processors used in technical systems is developing exponentially, and the capability of communication technology is undergoing similar rapid development. However, the human ability to cope with the complexities that technological development poses has not increased at the same pace. Thus, there is a gap between the possibilities that technology offers us and our capability of taking advantage of these possibilities. Consequently, it is becoming increasingly intricate and complicated to get an overview of the project and make sense of how all the pieces fit together. In particular, vital interdependencies may be lost in myriads of details.

One way to manage this situation is to use images for coordinating and communicating actions. The most common ones are Gantt charts, PERT (Program Evaluation and Review Technique) / CPM (Critical Path Method) charts, WBS (Work Breakdown Structure); images that were developed many years ago before the boost of complexity. These images are still useful, but it is also reported that they can become almost unmanageable in projects with many changes [1,2].

In complex development projects, “alternative” images have appeared, born out of pressing practical needs to enhance communication and cope with increased complexity. Examples of such images are: *anatomies* [3,4,5,6,7], *dependency diagrams* [8], *release matrices* [9], and *information flow diagrams* [10]. Recent findings indicate that alternative images are useful for coordinating complex projects. By and large however, the research community has more or less ignored these new instruments.

The purpose of this paper is to analyze what qualities the alternative images have that make them useful for managing complex projects, and why traditional images appear to be insufficient during these circumstances. As a theoretical “screening grid” for the analysis, we will utilize a particular framework called the Activity Domain Theory (ADT). This theory emerged in practice, in the telecom industry at Ericsson (a major supplier of telecom systems worldwide) as a way to analyse and inform the coordination of extraordinary complex development projects [11,12,13,14].

The paper is outlined as follows. First, we will sketch the contours of ADT and exemplify their constructs by looking at the Golden Gate Bridge (GGB) project carried out between 1933 and1937. Next, we will analyse traditional and alternative images by making use of the concept of *activity modalities* in the ADT. Activity modalities are proposed as basic dimensions along which human activity is coordinated; dimensions that can ultimately be traced to the phylogenetic evolution of the human cognitive apparatus. In other words, we will suggest that there are certain dominant thinking processes that humans make use of in coordinating their actions. In the discussion, we will summarize and interpret our findings. In conclusion we find that the alternative images are a means to manage integration activities and critical dependencies in the project. Typically, they emphasize common understanding and comprehensibility over formalism and rigour. In addition, the alternative images seem to be well aligned with the activity modalities, and thus resonant with how our cognitive apparatus conceives of coordination. For this reason, alternative images might be better suited to managing complex development tasks rather than traditional tools. We suggest that future research into the management of complex projects needs to take this finding into account.

The Activity Domain Theory – an integrating theoretical framework

Our point of departure is the concept of *mediation* in Activity Theory [e.g. 16,17], which refers to the idea that humans always put something between themselves and their object of work. Examples of mediational means in projects like the GGB are: dynamite, dredgers, pneumatic tubes, spinning saddles, derricks, etc. In general, mediational means can be tools of different kinds, but also communicative means such as signs, commands, directives, commitments and the like.

However as pointed out by Orlikowski [15], these means need to be *enacted* in order to become resources: "[The enactment view] starts with human action and examines how it enacts emergent structures through recurrent interaction with the technology at hand" [15, p. 407]. An artefact like a hammer does not become a resource unless someone recognizes its purpose and learns how to use it. Moreover, the cooperative nature of coordination implies that there is a shared or communal side of enactment; it cannot be confined to individual aspects only.

These ideas have been further elaborated in the Activity Domain Theory (ADT) by Taxén [11,12,13]. The essential features of ADT are as follows. A basic tenet is that enactment is always contextual:

> *"All productive knowledge is linked to and dependent upon an organizational context. In order to understand learning and accumulation of knowledge in an organization, it is necessary to define the content of the organizational context." [18, p. 54]*

In ADT, this context is called the *activity domain*. In the activity domain, actors are socially organized in order to produce something that is needed in society. The existence of the activity domain is motivated by need. Moreover, there is always something that the activity is directed to – the *work object*. The motive and work object are determinants for the resources needed. In the GGB project, the overall activity domain is quite naturally the project itself. The motivation for the project is obvious: to be able to transport people and goods efficiently across the Gate. An additional motive in the 1930s was to reduce the unemployment after the Depression. The work object is of course the bridge itself.

In ADT, *contextualization* is one of several *activity modalities.* An activity modality denotes a fundamental dimension in human activity along which resources related to coordination are enacted. Besides contextualization, the other modalities are as follows [11,13]:

- *Spatialization* – denotes the human capability of enacting spatial structures that signify which entities are relevant in certain activity domains, how these entities should be characterized and related to each other, and what state or condition they are in. Examples of spatialization in the GGB project are: blue-prints of the bridge, maps of the bridge and its land connections, etc.
- *Temporalization* – denotes the human capability of enacting temporal structures that signify actions and the dependencies between them. In this case, temporalization corresponds to the definition of coordination given by Malone & Crowston [19]: "Coordination is managing dependencies between [actions]." (p. 90). An example of temporalization in the GGB project is the project plan used to express the sequence of actions needed in order to complete the bridge.
- *Stabilization* – denotes the human capability of enacting stabilizing elements that signify which actions are regarded as valid and useful in a domain. Stabilization manifests itself as norms, values, habits, routines, methods, rules, standards, domain specific languages, etc. Without stabilizing elements, coordination is impossible. Examples of stabilization in the GGB project are safety regulations, units of measurements, construction methods, etc.
- *Transition* – denotes the human capability of enacting elements enabling the transition between domains. For example: the mapping and translating between domain-specific meanings. An example of a transitional element in the GGB project would be the contract regulating the interaction between the main project and the cable spinning sub-contractor.

In plain language, this may be expressed as follows:

- Human action is always situated (contextualization)
- Humans need to orient themselves spatially (spatialization)
- Actions are carried out in a certain order (temporalization)
- There are rules, norms, etc., that signify valid actions (stabilization)
- Activity domains need to interact (transition)

An illustration of the constitution of ADT is given in Figure 1:

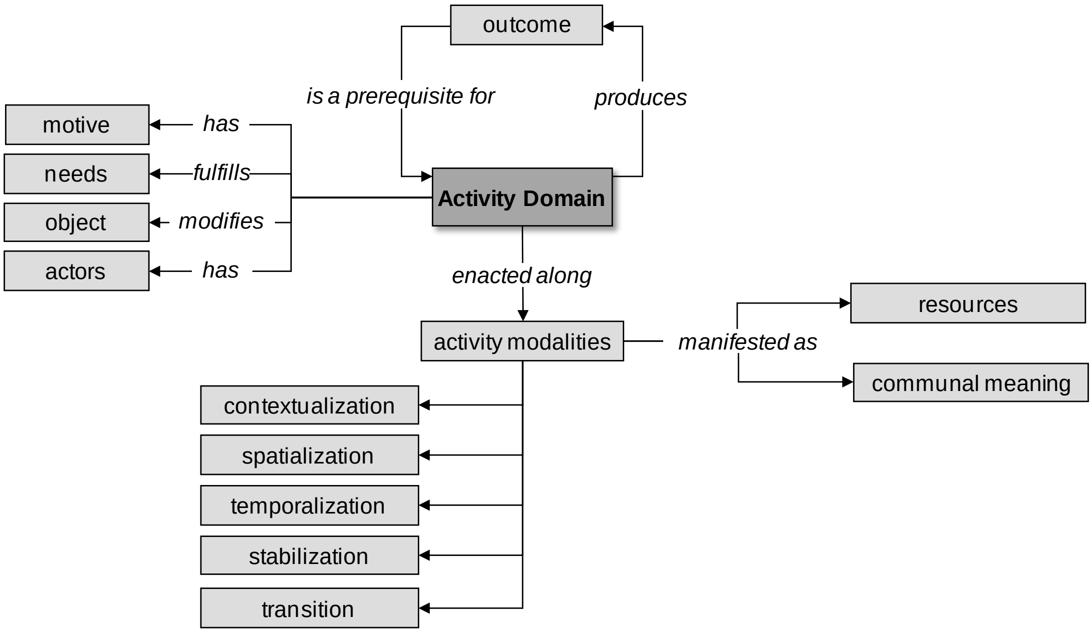

Figure 1: The constitution of the ADT

The construct of activity modalities is an attempt to identify distinct, albeit mutually interdependent modes of coordinating human activity. The term "activity modalities" is deliberately coined to connote with sensory modalities. In the same way sensory impressions are integrated by our brains into a coherent impression of reality, actions in different activity modalities are integrated into a coherent view of coordination by our cognitive apparatus. Ultimately, the activity modalities can be traced back to the phylogenetic evolution of our cognitive and neurophysical system [20]. In order to coordinate our actions, we need to enact communal resources, that is, mediational means along the dimensions expressed by the activity modalities.

In the following, we shall make use of the activity modalities as a guiding framework for analyzing traditional and alternative images in PM.

Traditional images

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

WBS

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 the scope) [21]. By breaking the work down into smaller elements, it is believed that risk and uncertainties will be reduced since each level provides a greater probability that every activity will be accounted for. In its graphical format, it is obvious why the WBS is often described as a project family tree [1]; hierarchically displaying interim and end project deliverables (see Figure 2):

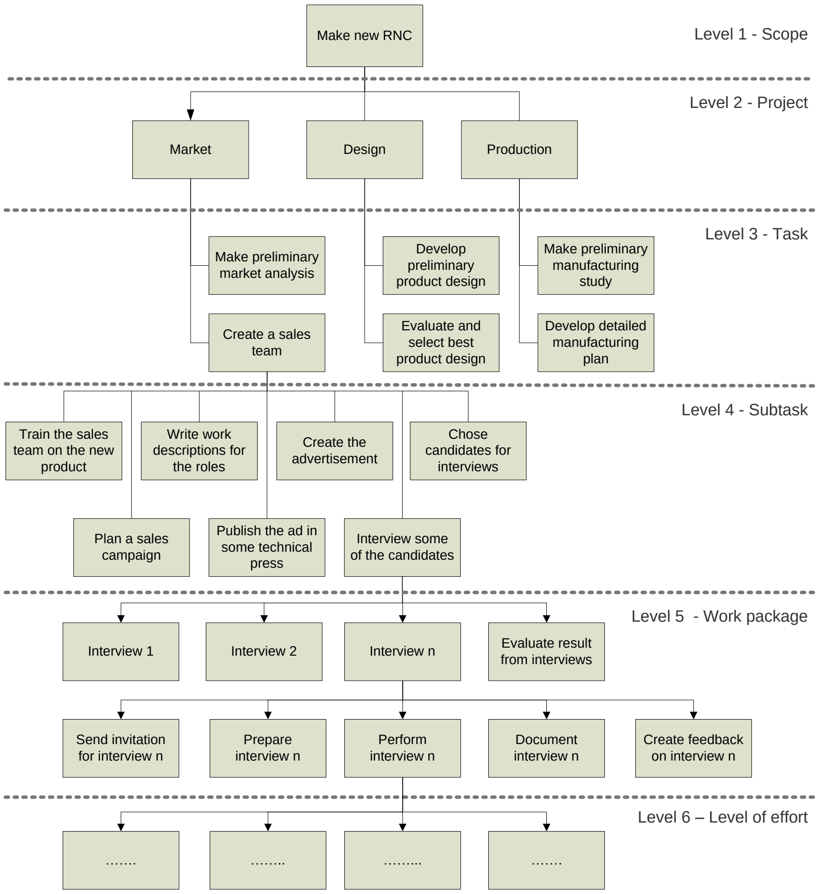

Figure 2: A WBS diagram

Although a variety of WBSs exists, the most common according to Kerzner [22] 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 following 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 3). It shows when the project and activities start and end against a horizontal timescale [1]. The chart is a useful tool for planning and scheduling projects, as well as for monitoring the progress of the project.

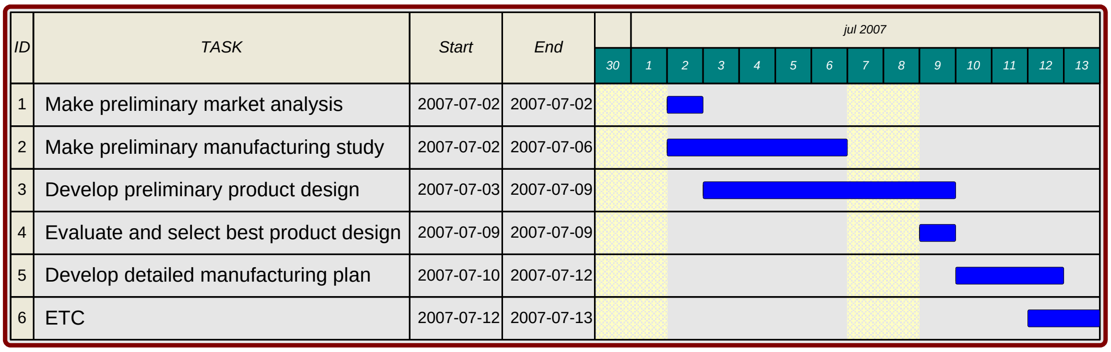

Figure 3: A typical Gantt chart

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. The difference is that activity duration estimation is deterministic in CPM, while PERT uses a weighted average to calculate expected time of activity duration [1].

A driving force behind developing a network diagram is its usefulness in highlighting interdependencies between 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 different modelling 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 not only pertaining to duration, but also with early and late start and finish (relative) time. 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.

Analysis of the traditional images

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

It can be observed that both Gantt and CPM diagrams display a structural form of "doing something directed to something", for example, "Develop preliminary product design". A verb and a noun indicate that two activity modalities are at play here: temporalization (the verb) and spatialization (the noun). The Gantt diagram and the network diagrams have a strong temporal flavour as indicated by the horizontal axis. However, the dependencies between the spatial elements are not shown, for example between "manufacturing plan" and "product design" in the example diagrams. Such dependencies, which indeed constrain the freedom in laying out the order of activities, must thus be kept implicit in the minds of the main actors. In essence, this means that vital dependencies might remain concealed in the project, something that quite naturally may have severe consequences.

Another observation is that WBS images appear to display several activity modalities in one image (see Figure 2). At the very top, the motive of the activity is given: "Make new RNC". At Level 2, the boxes seem to signify contexts of work division, something which is closely related to the transition modality. At Levels 3 to 5 there are clear indications of sequences of activities, that is: a temporal dimension. The naming of each work package shows the same structure as in the other diagrams: a verb and a noun. Thus, from an activity modality point of view, WBS images are based on unclear semantics, where several modalities are, so to speak, projected onto the same two-dimensional image. This may severely aggravate the construction of communal understanding about the project in more complex situations.

Moreover, even if several modalities can be traced in the diagrams, there is no indication of how these modalities are interrelated. Suppose for example, that a customer discovers during the project that he needs an additional functionality. This might impact functions deeply buried in the system. Without a clear view of the spatial dependencies between functions, it is arduous to re-plan the project.

Thus, the traditional images are weak at displaying dependencies between different modalities. The inclusion of activity dependencies in Gantt diagrams is one indication of increased attention of the importance of dependencies, however still within one modality only: 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[1], and appear timeless to the untrained eye. Another drawback with PERT and CPM in terms of complex system development, is the underlying assumption of a given functionality of the finished product. This may give a delusive impression that only time and resources need to be controlled.

Concerning 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 [1,2,23]. 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 continuously changing circumstances.

Alternative images

In this section, we will analyze the alternative images as exemplified by the *system anatomy*, the *increment plan* and the *integration plan* [1,2,5,6]. These images were devised in the early 1990s as elements in the so called Integrated Centric Development approach at Ericsson – a major supplier of telecommunication products worldwide. This approach is still in extensive use at Ericsson and has recently started to spread outside the company. These alternative images have been found useful in practice but have so far not been the subject of thorough theoretical inquires.

System Anatomy

The motivation for the system anatomy is the need to create a common architectural view of the system. The intention is that all stakeholders see the same image of how the system

[1] Except for Time-Scaled Arrow Diagram that is the only CPM method displayed against a timescale

works. The underlying idea is that an image is easier to agree upon than a traditional two-hundred page specification where everyone is left to create their own interpretation. The anatomy shows the dependencies between major functions or capabilities in the system; from the most basic ones to a fully operational system. An example of an anatomy of a processor is shown in Figure 4:

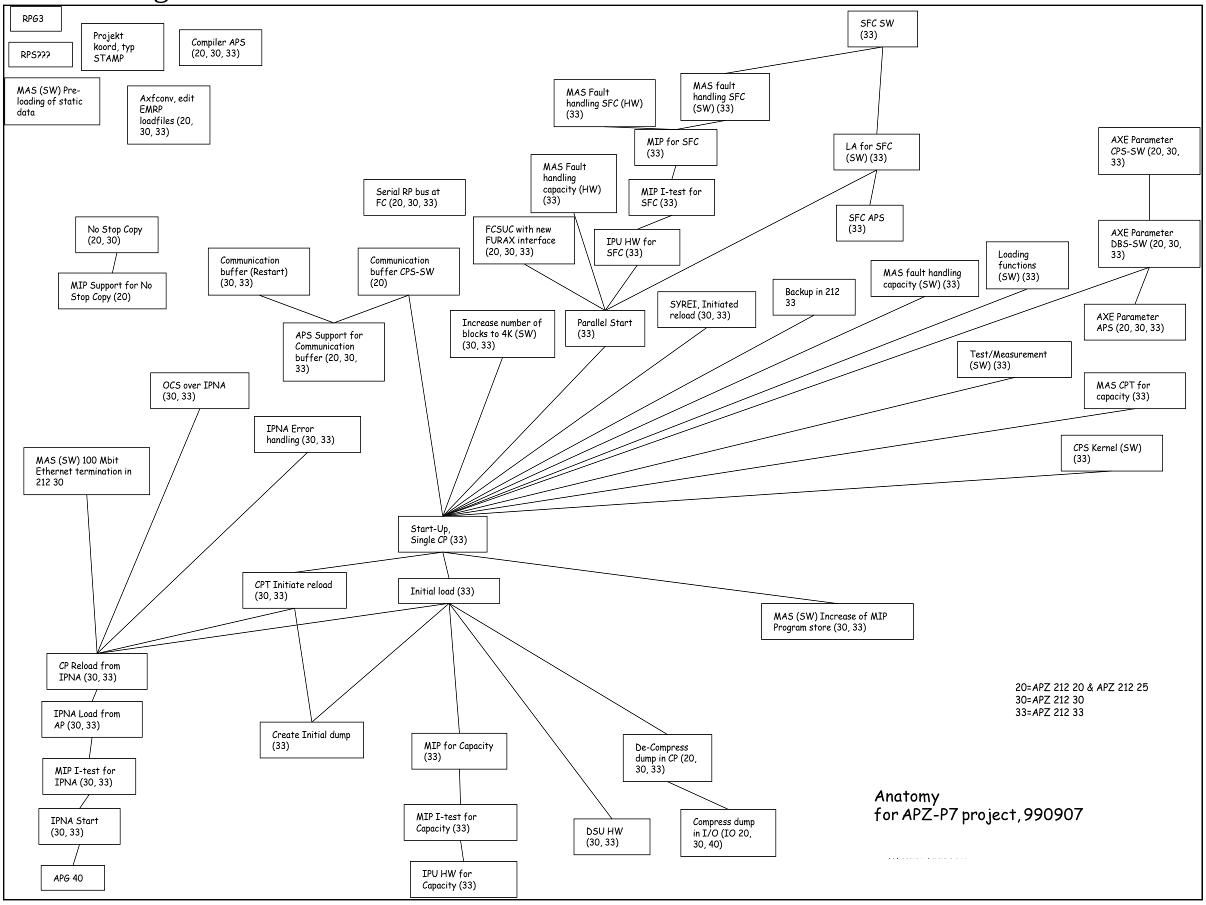

Figure 4: The system anatomy of a processor

The anatomy is created in workshops where the mindset should be: “if you ‘power-on’ what happens then …, and then?” This question is repeated until the final functionality is reached. The image may be more or less correct. This is not crucial. The decisive point is that actors can work and solve their part of the problem on the basis of the image they have.

Increment plan (work package plan)

The key point in the Integration Centric Development approach is to implement the system in the same order as the capabilities are needed according to the anatomy; hence the concept of “anatomy” implying how to “breath-life-to-a-system”. The development is done in increments, which are in fact are more or less equivalent to work packages (Level 5 in Figure 2) in a traditional WBS.

The motivation for the increment plan is the need to find a common view on how to implement the system. The capabilities in the anatomy are grouped into increments in such a way that the resulting sub-system after each added increment can be verified. In line with the metaphor of the anatomy, this could be seen as defining the major ‘organs’ in the system. As a matter of fact, this second step was called “Organic Integration Planning” in the early days of its use at Ericsson. In Figure 5, an increment plan for the same processor as in Figure 4 is shown:

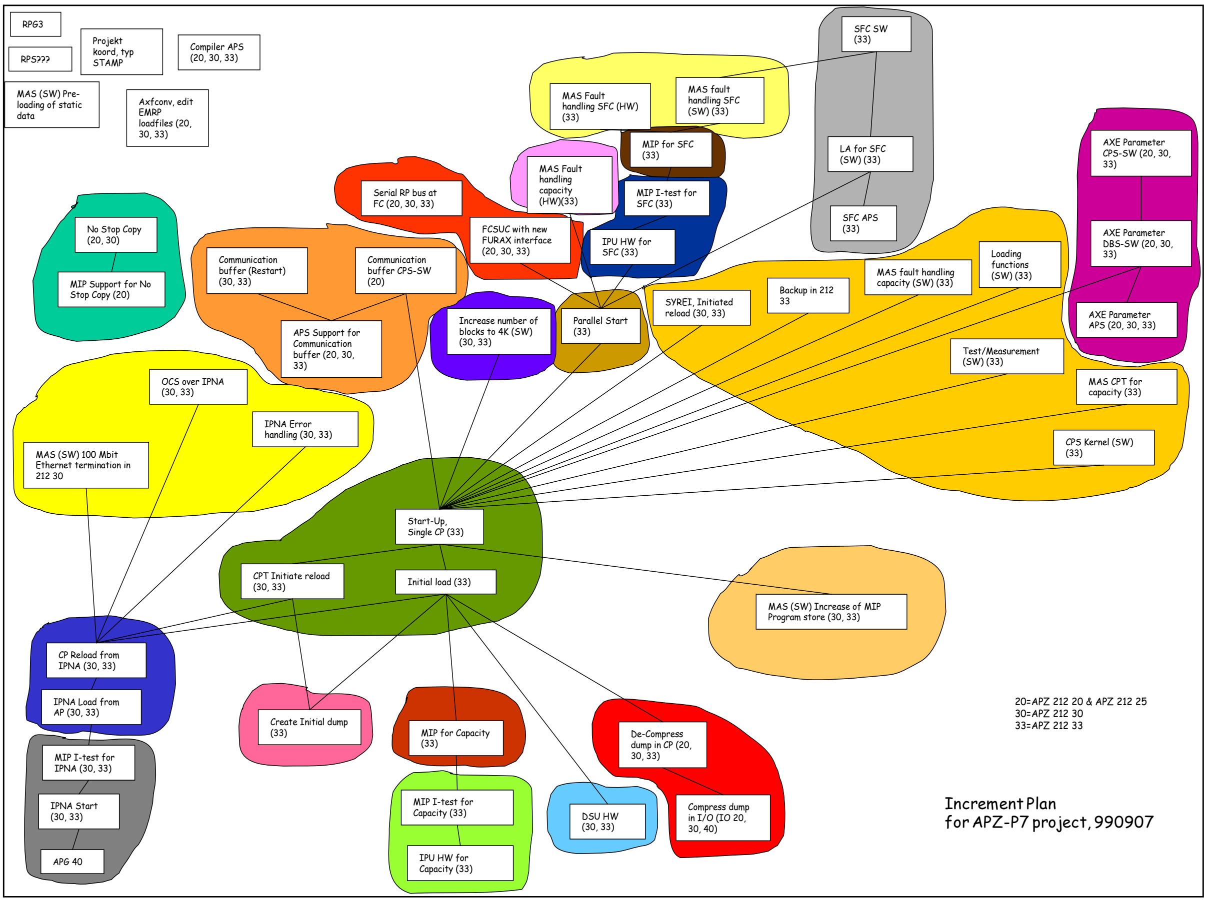

Figure 5: An increment plan for the development of a processor

When defining the increment plan, design and testing are parallelized as much as possible. The plan describes in what order increments 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.

Integration plan (project plan)

The motivation for the integration plan is the need to control what is delivered when, and from whom. When the plan is created, resources are assigned and dates for deliveries of the increments settled. For each increment, traditional time and resource plans are made as well. The integration plan also clarifies the receiver of each internal delivery. Thus, it focuses on the dependencies between subprojects. In Figure 6, an integration plan for the processor is shown. It can be seen that this plan is a ‘tilted’ variant of the increment plan, hence signifying a time line:

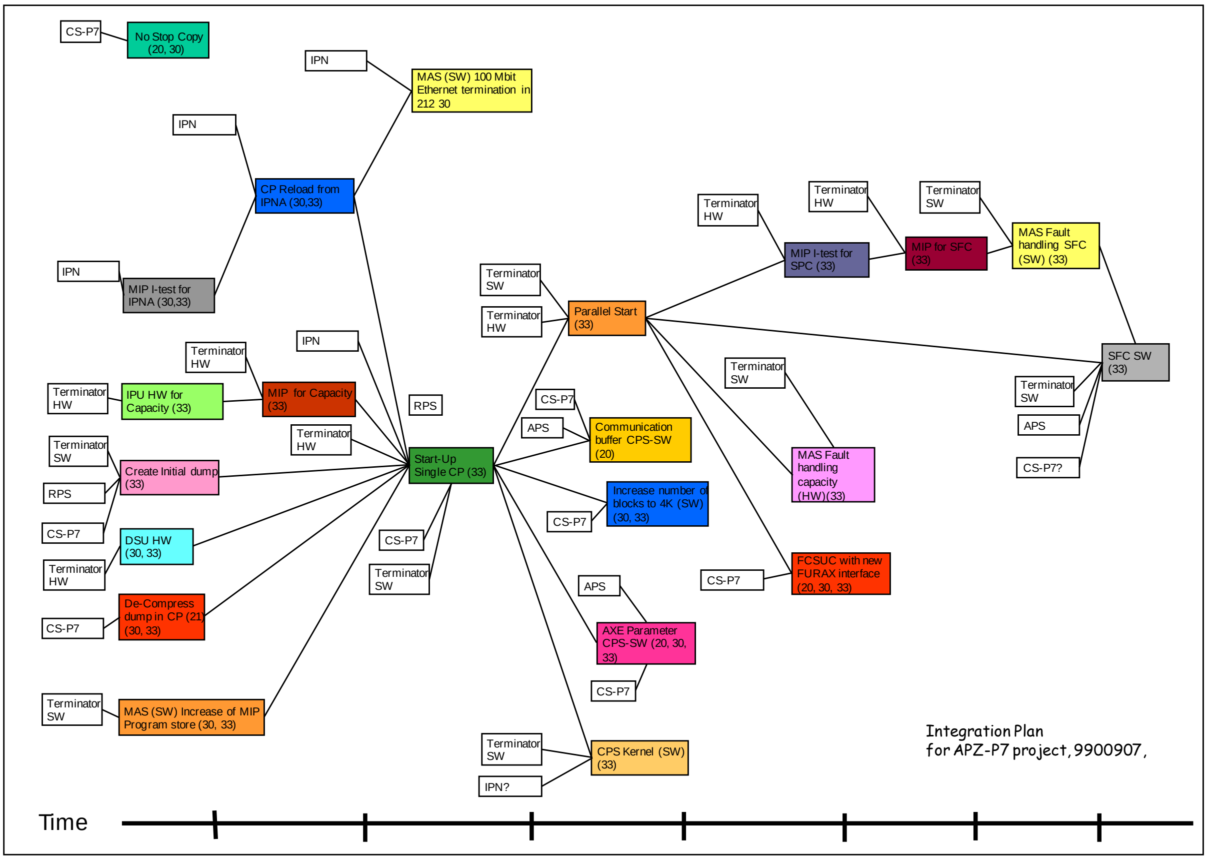

Figure 6: An integration plan for the processor project

The focus in the integration plan on dependencies between subprojects clearly shows the impact of a delay in the project. [23]. 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 integration plan looks similar to a CPM-diagram. However, the integration plan and the CPM-diagram are derived in completely different ways.

Analysis of the alternative images

In the alternative pictures, there is an obvious integrative perspective with a clear focus on the product that is to be delivered to the customer. Moreover, these images also highlight critical dependencies of different types. Further, 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 increment plan shows the dependencies between increments, which can be interpreted as an image of activity domains and how these interact. Hence, the increment plan is well aligned with the transition modality. The integration plan has an obvious temporal character since there is a horizontal time axis in the image. Moreover, the three images in the Integration Centric Development approach are related to each other through the common basis in the anatomy. Thus, the dependencies between modalities are clearly seen.

Discussion

We have analysed traditional and alternative images used in PM. Our analysis departed from the concept of enactment and utilized the construct of activity modalities as a guiding framework. Some of the findings are:

- Traditional images are focused on optimizations and control rather than action and coordination.
- Alternative images are focused on dependencies and integrations, and emphasize comprehensibility and informality over formality and rigour.
- Both the WBS and the increment plan in the Integrated Centric Development approach 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 increment plan is based on dependencies between capabilities in the system to be developed. This is lacking in the traditional WBS.
- The Integrated Centric Development approach utilizes a consistent set of images, each addressing / emphasizing a particular activity modality.

A conspicuous difference between traditional and alternative images is that traditional images seem to "compress" different modalities into a single image. This is an indication of the need to control all modalities. However, since these are shown in the same image, it can be expected that the 'cognitive load' of deciphering 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 loosing the interdependencies to other modalities. It is as if the alternative images are more aligned with the activity modalities than the traditional ones, and thus more resonant with the way our cognitive system experiences and constructs the world.

In general, the alternative images are strongly associated with action. The images are not only used for reporting purposes – they are used as mediational means for anticipating possible actions and foreseeing the consequences of these actions. The anatomy in the Integrated Centric Development approach is in fact the central coordinating instrument in extremely complex projects. The action aspect of traditional images is much less evident.

The construction of the alternative images is a social accomplishment. The images turn out slightly different depending on the composition of the group of actors developing the images. Moreover, these images are constantly revised during the project due to various reasons such as changed requirements, new insights, improved ways of working, etc. This indicates that the actors involved are indeed enacting the images; they are turning the images into resources while simultaneously constructing a communal understanding of how to use these instruments. Thus, the enactment process goes beyond mere learning where actors are passively appropriating the use of already existing artefacts. Consequently, the call for focus on learning in projects, see [24, p.272], is a necessary, but not sufficient condition for managing complex projects.

It is sometimes claimed that only theoretical research can advance the state of Project Management (PM) [25]. Other researchers have taken the opposite stance [26]. Our findings are quite clear on this point; innovations in PM are always derived from pressing needs on the practical battlefield. It is virtually inconceivable that the alternative images would have emerged in academia. From an activity domain point of view, this is quite natural since the enactment process is inherently tied to the work object and the motive of the domain. However, theoretical research has an important role to play in analyzing and explaining events, and making informed suggestions on how to transfer findings to other contexts. Also, theoretical insights may point to ways of improving practice. Thus, the interplay between theory and practice should be the solid ground for advances in PM.

An extensive inventory of the PM literature by Pollack [24] indicates that there is a shift in PM from the ‘hard’ paradigm to the ‘soft’ one. The hard paradigm denotes a focus on stability, predefined goals, control, reductionist techniques and the project manager as the ‘expert’. Up until now, this has been the prevalent paradigm in PM. However, more and more evidence is being gathered, pointing towards the conclusion that the hard paradigm cannot cope with turbulent environments, unstable conditions, moving targets, learning ‘on-the-spot’ and so on.

An indication of how to approach a more soft paradigm is given by the ability of the alternative images to cater to what might be called ‘federative control’ or self organizing teams, enabling the total project manager to coordinate only what is necessary. At Ericsson, where the anatomy concept has been used, it has been possible to transcend from a traditional PM approach to a more self-organizing approach [14]. Thus, the alternative images may be one set of instruments for advancing the shift from the hard paradigm to the soft one.

However, according to Pollack [24], PM appears to lack a coherent, underlying theoretical basis that would illuminate the path towards a softer oriented paradigm. We suggest that the Activity Domain Theory may provide such a basis. There are several reasons for this rather bold claim. First, the theory addresses the fact that PM is about coordinating different organizational units, working on diverse work objects and enacting dissimilar local meanings and resources. This is addressed by the activity domain construct. Second, the soft paradigm is inherently related to human and social issues, like the construction of meaning and the nature of human activity. As we have argued, this is a fundamental concern in the theory. Finally, the Activity Domain Theory provides guidelines on how to operationalize its theoretical constructs, that is, the theory is an instrument in itself by which it is possible to make a difference in practice.

To summarize, the findings indicate that future inquiries into managing complex projects should be directed towards exploring mediational means that are aligned with dominant activity modalities, however, without detaching the mutual interdependencies between these modalities.

Conclusions

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 inadequate for this purpose. We have investigated the striking observation that extremely complex projects are coordinated and monitored by, in principle, very simple images that are quite distinct from the traditional ones. Our main finding is that the alternative images appear to resonate with dominant activity modalities and their interdependencies according the Activity Domain Theory. Until now, these images have been sparsely treated in the PM-literature or ongoing research. We suggest that future research into the management of complex projects should pay attention to the alternative images, and in doing so, take our findings into account.

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