S Special Issue on the Classics in Project Management

Gantt Chart and the Scientific Management in Projects

Joana Geraldi and Thomas Lechler

Paper published at the International Journal of Managing Projects in Business. Cite as:

Geraldi, J., & Lechler, T. (2012). Gantt Charts revisited: A critical analysis of its roots and implications to the management of projects today. International Journal of Managing Projects in Business, 5(4), 578-594. (Note: Top 10 most downloaded articles of the journal since publication)

Abstract

Purpose – This article explores a classic tool in projects and its conceptual roots: the Gantt Chart. The 'Gantt Chart' is one of the most used project management tools today. However, it was not developed for projects, but for repetitive routine operations at the pinnacle of scientific management. We explore the principles and assumptions on which the Gantt chart is based, and its consequences to how we conceptualise projects.

Design/methodology/approach – We explore the historical development of the Gantt Chart and how it has been used. We derive from it the key principles on which the chart is based on, and analyse the consequences of these to how we conceptualise projects, project management, project managers and success.

Findings – The Gantt Chart provides a good example of how we have chosen to perpetuate hard over soft. While a Gantt chart can be useful to cope with some of the 'complicatedness' of projects, and embraces the importance of time and timing, it is based on flatted assumptions about (at least some) projects. The consequence is an equivocated understanding of success, and propagation of a management approach that is unhelpful to cope with uncertainty and change.

Originality/value – While the majority of contemporary project management thinking already accepted that these are flatted assumptions, the practice is still pretty much embedded in a mechanistic paradigm. By showing its roots, we hope to make some of its limitations more evident to practitioners and academics.

Keywords – visualisation, scientific management, Gantt Chart, uncertainty, project control

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1 Introduction

This article explores a classic tool of project management, the 'Gantt Chart'. The Gantt Chart is one of the most used planning and controlling tools in projects today. In a survey with 750 project managers, the Gantt Chart was the fourth most used tools out of 70 tools and techniques associated with project management (Besner & Hobbs, 2008). Indeed, we can hardly imagine project management practice or training without it. The Gantt Chart is part of our shared language. While we could not be sure whether academics and practitioners read or know about the work of Sayles and Chandler (1971) or perhaps even Morris and Hough (1987), we do know that we are all familiar with the Gantt Chart, and many – perhaps even the majority - have used it. Thus, Gantt Chart is part of what connects the members of project management community.

Taken that management discipline is replete of fashions and fads (Abrahamson & Fairchild, 1999), the Gantt Chart is remarkably resilient; it has been developed nearly a hundred years ago (Wilson, 2003), and survives until today despite numerous innovations in the area. In the 1950s, more sophisticated scheduling techniques were introduced (Morris, 1994), such as PERT (Program Evaluation and Review Technique) and CPM (Critical Path Method) methods. Unlike the Gantt Chart, these tools enabled the analysis of more complex relationships between the tasks and the uncertainty of each task's duration. With such precision, the critical path could be better calculated and understood. Still, the use of Gantt Chart at the time didn't decline, quite the opposite, it increased (Wilson, 2003); the tools were used in combination, and the outcome was visualised through the Gantt Chart. Later, Earned Value was introduced, and provided a more holistic understanding of project progress by linking cost, time and progress into one tool. In the 1990s, the concept of Critical Chain was introduced (Goldratt, 1997), which highlighted the influence of behaviour aspects into projects. Still, the Gantt Chart remained an important tool both in planning and controlling project schedules; so much so that popular project management software, such as MS Project and Primavera, uses the Gantt Chart as the main visual representation of projects.

The Gantt Chart is simple, intuitive, practical and useful visual representation of project activities and durations, which can perhaps explain such resilience. Further, the Gantt Chart is instrumental to enhance our cognitive ability to cope with structural complexity - coordination of a large number, diverse and interdependent tasks (J. G. Geraldi, Maylor, & Williams, In Press). MacNeice (1951)'s experiment provides a good indication of how powerful Gantt Chart can be; 300 management students were faced with complex production planning task, when asked to resolve it intuitively only 1% could solve the problem, when given Gantt Chart, all students developed a solution in 15 minutes. The chart is also a useful tool to communicate the project schedule and create a shared understanding of the progress (and lack of progress) of tasks. This aids the management of projects. For example, project managers can use the Gantt Chart to point to potential schedule delays and focus the project team's attention on the critical tasks to the delivery of project in time.

However, it has also important limitations. We will show that the Gantt Chart was not created for the management of projects, but for repetitive, routine operations during the pinnacle of the scientific management. We analyse the historical and current use of the Gantt Chart and show that its principles still resembles an image of the rational and deterministic approach to project management (Maylor, 2001) rooted in Scientific Management principles – what we call the Gantt Chart's Logic. While the majority of the contemporary project management thinking already accepted that this logic is out-dated and inappropriate to several, if not all projects (J. G. Geraldi et al., 2008), the practice is still pretty much embedded in a mechanistic paradigm. By showing its roots, we hope to portray a caricature of project management and so with help practitioners and academics to understand its limitations.

The article is divided into four parts The paper begins by exploring the historical development of the Gantt Chart and how it has been originally used. The second part of the article, we explore how Gantt Chart are used today by analysing the scheduling activities proposed in the PMI Body of Knowledge ®. We derive assumptions and principles inherent to this process, which we termed the Gantt Chart Logic. The third part explores each principle in detail, and shows how its inherent assumptions and principles are still embedded in Scientific Management. In the last part of the article, we explore the consequences of the Gantt Chart logic and conclude with research questions to explore alternatives to the Gantt Chart logic.

2 Gantt Chart: Origin and Development

As we started the work in this article, we had hoped that the reason for conflicts between Henry Lawrence Gantt and Frederick Winslow Taylor (Wren, 1987) was Gantt's exposure and interest in projects (unique, uncertain, temporary endeavours), in opposition to repetitive operations as was Taylor's main concern. We had hoped to find in the original work of Gantt some hints as to the uncertainty of projects, some tips or wisdom on the use and limitations of Gantt Chart that have been lost in the development of knowledge over the years.

What we found though was that Gantt developed his methods for repetitive routine operations. Gantt was a prolific writer and had an impressive intellectual productivity, he has published over 150 titles and three major books: 'Works, Wages and Profits', 'Industrial Leadership' and 'Organizing for Work'. He also patented over twelve inventions, has made numerous presentations in the American Society of Mechanical Engineers and lectures at Stevens, Columbia, Harvard and Yale (See Box on Life and Work of Henry L. Gantt for more detail). So it could well be that among this large body of work, he had mentioned projects; we do know that he has studied project-like activities too such as the production of ships. However, we can assert that projects were not his key concern as none of the three books mentions projects or project-like activities. He was, as much as Taylor, concerned with the efficient and effective use of resources and increase of productivity in repetitive, routine operations. This means that one of our most basic tools and the foundation of the practice of projects is intertwined with principles of scientific management.

The first Gantt Chart-like visualisations were used to 'fix the habits of the industry'. Gantt developed visualisation tools that allowed foremen and workmen to check the current productivity level of each employee and observe which employees have under- or over-performed. The idea was to monitor and reduce idle time, and increase personal accountability for levels of productivity. The productivity of each employee was recorded across time in a tabulated system, where red meant lost of bonus and black gain of it. It acted as a motivation and control mechanism, where both managers and workers could quickly visualise their achievements.

Gantt also used graphics extensively to monitor the utilisation of resources, e.g. control costs, daily production balance, quantity of work per machine, expense of idle machinery among others (Wren, 1987, pp. 136). An early version of the Gantt Chart was used to monitor the production progress with permanent record of how the order was fulfilled (Figure 1). Here, although the sequence of operations was not stated in the chart, it contains start and end dates.

Figure 1 here

Until then, the charts were mainly focused on the past (monitoring what had happened) instead of planning for the future. It was when Gantt faced the production network for war supplies in the 1914 in the US that the Gantt Chart as it is known today was developed. The production network lacked appropriate coordination mechanisms. *"Plants were scattered all over the nation, shipments were late, warehouses crowded or disorganized, and the Ordnance Department and the Navy used their resources poorly"* (Wren, 1987, pp. 136). The systems were also overwhelmed as orders increased from hundreds to millions (Clark, Polakov, & Trabold, 1922, p. iii). Gantt realised that it has been wrong to manage schedule based on quantities; the essential element is time (Alford, 1934). It was this insight – the importance of time – that made the chart so useful for projects.

His solution[1] was very similar to what we know today as the Gantt Chart. Unlike other versions, the focus was not only in the present, but also in the comparison between plan and actual. The work realised (thin lines) is compared with the work planned (thick lines) for each task (Figure 2). This is one of the principles that came to be pivotal to project management thinking.

Figure 2 here

Unlike Gantt Charts of today, it also provided a visualisation of the issues hampering higher efficiency, shown by the letters – e.g. W, waiting for set up, M, lack of material, H, lack of help, as Clark (1925) explains:

> *"The Gantt progress chart enables the manager to keep before him all the promises he has made, to concentrate his attention on overcoming obstacles and avoiding delays, and, when it is impossible to live up to a promise, it enables him to give the customer advance notice of the fact" (Clark, 1925, p. 84).*

Thus the original Gantt Chart was not limited to coordination of the production, but also helped to recognise patterns of failures instigating double loop learning, e.g. if 'M' dominates all issues and reasons for delay, managers can look more in depth at what is happening with material deliveries, and how to improve it.

In summary, Gantt Chart was not developed for projects, instead for the coordination of the network of production facilities, and it was developed at the heart of scientific management movement, and embodies its ethos, and therewith its assumptions and principles.

Alford (1934, p. 180) recognized that these charts can be valuable to plan things "less concrete" and Kimball (1925, pp. 149-150) discussed the usage of Gantt Charts in operation scheduling and claimed that *"The Gantt chart is perhaps the most effective form of graphical schedules''*.

Although it was originally established as a general production planning tool by the mid-1920s, Gantt Charts has been applied to a variety of fields including project management. Wilson (2003) reviewed the early discussion about the usage of Gantt charts. Moore (1951) and MacNeice (1951, p. 57) are among the first researchers to directly comment on the usefulness of Gantt charts for managing projects. However, the earliest illustration of a project based Gantt chart was found in Koepke' work (Figure 3 1941, p. 391). The Gantt chart which was more similar to what we used today in project management appeared in

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[1] Gantt himself though did not publish the Gantt Chart in his books. It was Wallace Clark, a member of Gantt's consulting firm, and colleagues that popularised the graphic in the first decades of the 20th century through the Book 'The Gantt Chart: a working tool of management' and extensive consultancy. For a detailed account on the development of Gantt Chart see Clark (1934). Later, Wilson Wilson, J. (2003). Gantt charts: A centenary appreciation. *European Journal of Operational Research, 149*(2), 430-437. claims that the origin of the Gantt Chart is still unclear, and may not have been developed by Gantt himself. This view contradicts that of Clark and Wren's (1987) account of the development of Gantt Chart.

Muther's work (1944) and was called schedule charts. The application of Gantt charts in project management was greatly increased with the development of modern project management in mid-1960s. Specially, the advent of the Critical Path Method (CPM) and Program Evaluation and Review Technique (PERT) contributed to the wide expansion of interest in Gantt Charts in project management (Weaver, 2007; Wilson, 2003). The use of Gantt charts as a complementary method for project planning and management then became more prominent. The subsequent development of micro computing and its stimulation of PC based project management packages have revived Gantt charts (Wilson, 2003).

3 Current Use of the Gantt Chart and its underlining Assumptions and Principles

The historical overview demonstrates that the Gantt Chart aided the implementation of Scientific Management practices. In this section we will explore the current use of the Gantt Chart and show that its assumptions and principles are still intertwined with Scientific Management thinking. The PMBoK® (PMI, 2008) guidelines were used as a starting point in defining common steps associated with the current use of Gantt Charts in project scheduling. We have chosen the standards of project management in oppose to the literature on planning or visualisation techniques because the objective was to explore the contemporary yet 'traditional' project management practice. Taken the number of certified PMPs and member of the PMI community, we take the PMBoK® would be the most well known work in current practice (not necessarily the most practiced or least criticised though). We then derived underlying assumptions and principles for each step. Table 1 summarises the result of this analysis.

It is important to note the limitations of our analysis upfront. Firstly, we cannot guarantee that the steps resemble the current use of the Gantt Chart. We agree that project professionals are unlikely to follow the steps rigorously. Yet, taken we start our analysis with the mostly recognised standard of project management, we argue that the steps are close at least with what is widely accepted among the practitioner community, and that the steps resemble the mainstream state of practice in project scheduling. Secondly, a principle can be related to more than assumption, and vice versa. This is because they are intertwined in the 'fabric' of the Gantt Chart's Logic, and emerge in different parts of the process. Thirdly, this method does not guarantee an exhaustive identification of principles involved with the use of Gantt Chart. However, what it does guarantee is that the assumptions and principles derived through the method are valid. We opt to follow Foucault's critical history approach; the aim is to 'problemitise', i.e. not in search of the whole truth but just enough to put the current established truth in doubt (Foucault, 1971).

Table 1 here

The next paragraphs explore each of the principles for the application of the Gantt Chart's Logic, namely: unidimensional, objective, deterministic, analytic, accountable and sequential. For each principle, we:

- provided a general definition of the term
- linked it with the logic and concerns of the Scientific Management

- explored its resonance in projects in general
- analysed regarding its impact in what we mean by projects, project management, project managers and success.

3.1 Unidimensional

Gantt Chart is unidimensional, i.e. it promotes a focus on one dimension over others. In particular, the Gantt Chart focuses management attention on efficiency, as measured through time and timing.

Efficiency was at the heart of the scientific management and, arguably, an appropriate response to the context of war. Scope was already pre-defined, and well-known, quality and client's satisfaction were less of an issue at the time. Consequently, Scientific Management is instead concerned with the reduction of waste of human effort by maximizing efficiency, i.e. maximise work that can be done in a given period of time. Efficiency, measured and visualised through time, was emphasised other any other variable, be it quality, employee's wellbeing, organisational learning and growth, diversification, etc. Thus, Scientific Management is *unidimensional*. The Gantt Chart embodies this principle by showing work progress by time. Actually the control of efficiency through time and timing was the great 'insight' in the Gantt Chart. As mentioned in the last section, the volume of production increased dramatically, and the management focused on delivering as quickly as possible. The complexity of the operations increased, and the work needed to be coordinated across a network of production facilities spread all over US. Coordination through time and deadlines played a crucial role to meet the volume necessary in times of war (Wren, 1976/1987).

Likewise, the power of time and timing to coordinate work has been identified in project management; meeting schedule deadlines becomes the heart beat of projects (Lindkvist & Soderlund, 1998), and represents what is equal across parties involved in projects and therefore has the potential to integrate them – what Dille and Söderlund (2011) termed isochronism alluding to the concept of isomorphism. So much so that the Gantt Chart defines, quantifies and manages interfaces in terms of time and sequence, not content.

The importance of time to projects goes far beyond a coordination mechanism. Projects are defined by being temporally bounded, and it is exactly this characteristic that makes projects an interesting and unique context for scholars in organisation theory (Dille & Söderlund, 2011; Lundin & Söderholm, 1995; Packendorff, 1995), team dynamics (Gersick, 1988, 1989), among others. Focusing on time allow us to understand projects as a task to be completed, something that has a clear start and end.

The Gantt Chart encourages a project management focused primarily in monitoring the schedule, i.e. whether tasks have been completed on time and the consequences of delays to meet its pre-defined delivery date. Project manager becomes the 'keeper of the charts' and computer operator, and project management is quickly reduced to the management of schedules[2] (Maylor, 2001). However, projects are not only about time, and the use of Gantt Chart may promote a project management that is overly preoccupied and focused on time over other relevant aspects involved in managing a project, such as the value creation and realisation, development of relationships, exploitation of opportunities.

This is also problematic as time is not necessarily the key success criterion. While in the beginning of the twenty-century, the focus on time and efficiency was understandable (although not without criticism[3]), such a context is quite unusual in today's turbulent and uncertain business context, with clients and customers expecting customised products and services, and actually the emphasis on time over other variables is no longer in line with today's understanding of success criteria (Jugdev & Müller, 2005). It could be argued that there are contexts in which time is key and should be the heart beat of the project, such as venues for Olympic Games, where significant delays will compromise the project benefit realisation. However, even in such situations emphasis on time could cause problems. Engineers may need to go through short cuts that may impact the project dramatically. The Challenger Project presents a good illustration. Time was indeed key, any delays could compromise the mission, however the pressure to launch on time compromised other relevant success criteria such as safety (Vaughan, 1996).

Some may argue that the issue is not to focus on one dimension, but that time should not be that dimension, perhaps benefit realisation could be that 'magic' dimension. While this may not be directly related with Scientific Management, it does resemble another quite controversial figure of our past – the Machiavelli's principle of ends justifies the means, which has quite well-known and heavily debated limitations, and is not as prevalent among experienced practitioners (Miesing & Preble, 1985). Thus, while time is powerful coordination mechanism and instrumental to increase team motivation, a project, project management and project manager overly focused on time is 'dangerous'. Project management can give more emphasis on a criterion over others, but still it needs a more balanced approach between several dimensions in order to deliver benefits through a sustainable and ethically justifiable process.

3.2 Objective

Gantt Chart promotes an objective understanding of reality, i.e. the object (in our case, the project and its tasks) exists independent from the person or mind (IEP, 2011). There is one truth, one right way, and that can be determined. In management terms, the bars in the Gantt Chart represent an objective (and precise) description of what it is to be undertaken and how long it takes to do it.

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[2] Interestingly, the current response to the wish to 'keep the charts' has been not to revise this principle, but instead to add another layer of management, the PMO (Project Management Offices) and schedule managers, responsible to keeping the charts, while the project manager has the time to manage the project Geraldi, J. G. (2008). *Reconciling Order and Chaos in Multi-project Firms: Empirical Studies on CoPS Producers*: Sierke..

[3] Even in such context, the emphasis on efficiency was heavily criticized at the time. For a comprehensive account see e.g. Wren (1987).

This was the ethos of the Scientific Management. Taylor and his proponents wished to reduce the systematic soldiering, i.e. *"deliberately working slowly so as to avoid doing a full day's work"* (Taylor, 1911, p. 3) by developing a 'true science of work' and systematically defining what would be the *fair day's work* rewarded with a *fair pay* – Taylor's first principle (see box 2). Frank and Lillian Gilbreth increased the precision of Taylor's work and introduced the time and motion studies: the work is analysed in detail, so to establish with a high degree of precision the best way to do the task and the exact time needed to do so. This was not necessarily Gantt's view, as he puts emphasis on the habits of the industry over the exact definition of the task (Gantt, 1919). However, Gantt Charts are not used in projects with the view of encouraging specific habits, but rather to create (in many cases also impose) one (the optimal) view of how the project should progress and at what rate.

Surprisingly this logic was very well embraced in the use of Gantt Chart in project management today. Scientific Management propagates that there is one best way to execute a project, and that it can be defined and visualised in the Gantt Chart. It is *possible* to define objectively the scope, steps to be undertaken, its durations and interfaces, and measure progress.

This principle impacts our conceptualisation of 'projects'. The Gantt Chart's Logic suggests that projects exist regardless of people involved in it. This is dangerous, as the Gantt Chart becomes the 'statement of reality' (Maylor, 2010, pp. 146). The project manager delivers the planning of the tasks top-down, instead of passing the responsibility for time plan to team members, and consequently, dialogue and adaptations are avoided already in the early stages of the project. The legitimisation of Gantt Chart as 'the' project plan increases with the use of project management software.

> *"Whilst computer-generated graphics and colour print-outs have given Henry Gantt's production planning bar chart a perceived new lease of life by imbuing a sense of certainty and they have retained their credibility despite contrary evidence, particular problems arise here." (Maylor, 2001, pp. 95)*

Thus, the objectivity of the Gantt Chart has ontological implications. It denies that projects are enacted – projects are not a predefined 'thing' to be managed, a phenomenon, or pre-existing 'thing to be managed' but they are enacted by people working on them (Kreiner, 1995); its vision, goals and management processes are constructed by its participants based on previous experiences (Packendorff, 1995). Further, project has a history. Activities later in the project depend on the success or misfortunes of the past activities, and therefore following plans blindly would be rather less efficient as intra-project learning is not incorporated (Andersen, 2008; Engwall, 2003).

Secondly, objectivity implies a management of projects by following the Gantt Chart. If we were to consider project plans objectively, we would also need to accept that neither politics nor interests influence estimates in the Gantt Chart, nor the progress reports. Assumptions that have been shown to be at odds with project management practice. For example, Flyvberg and colleagues showed that 'guesses' of time and cost are consistently overly optimistic. They found it suspicious as estimation tools and experience should have aided decision makers with more reliable information to develop more precise estimations. Moreover, if estimations were wrong due to lack of knowledge, there would be a balance between optimistic and pessimistic estimations. Therefore, they suggest that initial plans are a political act instead of a rational and objective definition (B. Flyvbjerg, Bruzelius, & Rothengatter, 2003; B Flyvbjerg, Holm, & Buhl, 2002). With the 'plague' of high failure rates in project, scholars do strive (and should continue to do so) for better understanding of the reasons of failure (developing a large body of work under the headings of 'critical success factors'), but we also need to question whether they were poor and poor to whom (e.g. Hodgson & Cicmil, 2006), opening to a better understanding of politics in project management, a notion that does not fit the Gant Chart logic.

It is also assumed that there is one best way of conducting and organising project tasks, and the task of project manager is to define how, communicate it to the team and ensure that the project is following it. In other words, it is possible to *define* and *measure work, its duration and interdependencies.* The Gantt Chart becomes an instrument to develop, communicate and crystallise the 'right' project schedule. It promotes a 'management by planning' in oppose to a 'management by organizing' (Williams, 2005), a project as task not as organization (Andersen, 2008).

It had important consequence to the practice of managing projects. Managing through the Gantt Chart makes us focus on the gap (planned vs. actual). Having the baseline as objective freezes our mind, create own reality that is not necessarily in line with the potential alternative realities, which are not seen as the baseline filter. Williams (2005) though argues that methodologies which allow projects to "emerge" are more appropriate than the traditional fully pre-planned modus. A decade earlier, Eisenhardt and Tabrizi (1995) come to similar conclusions.

Another consequence of an objective logic is on how we establish reason for mistakes. As mentioned above, the original Gantt Chart provided a visual representation to the reasons for delays. This practice could have been responsible for single and double loop learning (Argyris, 1977) improving efficiency and effectiveness of operations at the time. While this may appear attractive at first sight, attribution to delays and changes in projects to one single or very limited number of causes (Williams, 2005); such practice is overly simplistic and not fit to project contexts.

This also has implications to the role of project managers. It implies that progress can be measured objectively and the project manager can and should do this. It reduces the role of the project manager to find ways to ensure project is following the pre-determined path, and avoid variations.

Thus, success is defined as meeting the baseline, moving the project along with as little variation as possible. The validity and reliability of the baseline or the measurement of progress is not questioned.

Objectivity is quite appealing; why not to define an optimal way and follow it? However, as some scholars argued, in 'real projects' this is hardly observed (J. G. Geraldi, et al., 2008). Such principle though could be an aspiration in stable and unambiguous projects, where neither uncertainty, change nor behavioural complexity exists (J. G. Geraldi, et al., In Press), this is rather rare though.

3.3 Deterministic

Gantt Charts are mainly based on determinism, i.e. they assume that given certain conditions that can be established *a priori*, it is possible to determine everything that will happen; nothing else could have happened instead, and thus, a plan can be complete and embrace all potential challenges a project may face. In other words, it is expected that the world is predictable and we can predict it. This implies that tasks could be completely predefined, described and studied in detail; and therefore does not accept potential uncertainty in goals or methods, which is widely recognised in projects (Turner & Cochrane, 1993).

Determinism is implied in the first two principles of Scientific Management proposed by Taylor, namely the development of the science of work and the scientific selection and development of the worker (see Box 2). It is assumed that the process to perform a task can be standardized and that people could be trained to perform these tasks. This implies that tasks could be completely predefined, described and studied in detail; and therefore does not accept potential uncertainty in goals or methods, which is widely recognised in projects (Turner & Cochrane, 1993). The first two principles also evoke Taylor's notion of "one best way" of performing a task by separating planning from executing. Perfectionist planning should eliminate any need adaptations, and ensure the optimal execution of the task. Thus, such principles can only be applied if the context is predictable and deterministic.

In the context where Scientific Management was develop, change played a less important role in management thinking and rhetoric (Wren, 1976/1987) – quite surprisingly though, taken they were under war and changes in the society and economy abounded. However still, in the context of routine repetitive operations, change and uncertainty does play a less important role, at least in the operations of the firm. Today, determinism may be aspired by some, but it is no longer accepted, instead, the current management rhetoric is that of change and adaptation to a turbulent context.

However, determinism is also clearly present in the current use of Gantt Chart. As showed in Table 1, it assumes that it is possible to determine *a priori* a) the scope of the work and translate it into activities and b) the type of dependency between activities and quantify these in terms of time. This also assumes that it is possible to estimate the duration of each task with a high degree of certainty[4]. Thus, all potential issues that a project may face should have been identified *a priori*. Thus, the impact of 'truly' unknown-unknowns is not recognised, but instead perceived as the lack of foresight. Yet, there is an increasing awareness that unexpected events will happen (J. Geraldi, Lee-Kelley, & Kutsch, 2010; Hällgren & Wilson, 2008; Söderholm, 2008; Sun & Meng, 2008), and 'truly' unknown-

[4] One could argue that Gantt Chart, if used with tools such as PERT, could show pessimistic, optimistic and likely scenarios, and therefore consider the accuracy of the estimations. However, we still assume accuracy in the determination of the inaccuracy of the estimates.

unknowns exist and are likely impact the project (De Meyer, Loch, & Pitch, 2002; Loch, DeMeyer, & Pich, 2006).

The ability to determine what will happen underlines the predominant project management logic, define-execute: We define what is to be executed at the front-end, cement this in the contract, and then manage its execution. A classic analogy is that the soup is cooked in the front-end of the project, and all we have to do in the execution is make sure we eat it on time and to budget. So, if the soup is not well cooked or it turns out the client is allergic to the ingredients, there is not much we can do, either than adding salt and Parmesan – it is too late to change the recipe.

Thus, following this logic, projects are about turning *the* plan into reality, and project management refers to defining the scope and process and executing it, whereas gaps between the plan and current progress should be avoided or identified and mitigated. project manager's responsibility then is to plan so precisely considering all different scenarios and potential risks that gaps between plan and actual can be avoided, or at least identified quickly. As they do emerge then project managers should put the project 'back on track'. Project success is then not only about meeting the baseline, but being able to meet it without surprises.

It is not our intension to diminish the importance of the front-end to projects; there is plenty of evidence suggesting that we do need to plan, and there is undoubtedly the need to dedicate effort to the understanding of the scope and demands and build a relationship with the client and other project stakeholders (e.g. Cooper, 1988; Morris, 1994; Morris & Hough, 1987; Pinto & Kharbanda, 1996; Verworn, 2009; Williams & Samset, 2010). Instead, we argue that there is a need to recognise that the Gantt Chart's Logic promotes false sense of certainty and stability under conditions of uncertainty. If conditions of uncertainty occur more often it is possible that we become trapped by the constraints set at the front-end. Projects are too risky and costly to be left to the front-end alone. It is exactly at this first phases that projects are particularly uncertain, in some cases very political, project team is not well-formed yet, key stakeholders are still negotiating their roles, responsibilities and rewards. It doesn't appear to be the most adequate context for defining project success. What makes us dependent on our estimations and 'ability' (or wish) (B. Flyvbjerg, et al., 2003) to predict the future with high levels of certainty.

This principle has also consequences to the definition of what it means to be a project manager. Taken all that could happen in projects can be pre-defined (determinism), and one can define precisely one right way to undertake the work (objectivity), it is possible to determine a priori what project managers need to do in order to manage projects – a work code, train them accordantly, and implement sanctions for not following this code. In other words, project management can be defined as a professional only, i.e. a science and not an art.

3.4 Analytic and Accountable

Gantt Chart is based on analysis, i.e. our ability to divide into parts, breaking a complex topic, task, problem into pieces, to gain a better understanding of it. The whole is considered as the sum of the parts, and the best way to execute the project is divide it into steps and make people accountable for them.

It is needless to say that this was the basis of the definition of the 'science of work'. In the early phases of the industrialisation, efficiency was gained by the detailed analysis of the work. Previously, an artisan would make an entire product; he/she had ownership over the entire production process. With the industrialisation, and later the Scientific Management, the work of the artisan was broken into smaller tasks, each executed by another person. Efficiency and control over the work increased dramatically, and the need for skills reduced, and the worker became exchangeable, as a part of a machine (Wren, 1976/1987). Further, division of work is also related with accountability. The division and specialisation of work suggests that workers will be assigned to specific tasks only, and be accountable for this task.

In crude terms, a project becomes the sum of the tasks to be executed, and it is possible to assign people to each of these, and so define who is accountable for potential issues. Management is done by division of work and clear accountability – divide and conquer. It is the role of the project manager to ensure a good and clear partitioning of the work. Issues in interface between tasks are due to an 'erroneous' or sub-optimal division of the work, and can be improved. If a task is not completed on time, the person/group/organisation accountable for that task is to 'blame'.

However, the project fragmentation encourages focus on low level delivery and not the overall project effectiveness. Parts of projects are seen as silos, and optimized independently. As projects are uncertain and likely to change, grey areas between silos often emerge as project scope and context changes and are often source of conflict, especially between suppliers and client. Suppliers will focus on 'their task' and will consider the project to be successful if their task is delivered on time and budged, regardless whether this led to the strategic benefits intended by the clients. So, in the Gantt Chart's Logic, project success is reduced to the delivery of each task; taken that project is the sum of the tasks and these can be determined a priori, if every party ensures that their task is delivered, than the project will be a 'success'.

Finally, the professionalization of each element of projects also enforces the fragmentation not only of scope but also of the function of project managers. For example, we have often observed project managers that delegate risk management to the risk practitioner or consultant and had little ownership about the actions and consequences of risks in projects, and therefore fail to integrate risks into negotiations with client, conversations with team, etc. As with controlling systems, this begs the question whether risk management is still necessary if it is not informing decisions.

3.5 Sequential

The Gantt Chart visualizes the process of task execution as a sequence of tasks. This visual representation is appropriate for tasks that follow a clear sequence, in which each task is truly completed, and one can move to a next task; there is no need to revisit the tasks that have already been completed. Processes are sequential in manufacturing processes, and so much of the Scientific Management mindset assumes and expects a sequential process.

In project management, sequential process is best known and understood as the Waterfall process. For example, by the end of the design phase one reaches 'design freeze' and moves to the next phase. Following this logic, project manager's role is ensure that the process is followed in the right sequence, and each step is completed and freeze, so the project can move to the next. Project success then means that one 'gets it right first time', loops are sign for incompetence or 'sloppy' work.

The problem occurs for activities that are related in a circle, i.e. they have to be repeated until convergence to a solution or a specific level of quality is achieved. Software development processes are a good example. They start with the analysis of requirements, followed by program design and coding and finally testing. If a software module shows significant defects during the testing stage the cycle starts again either with the first or second or third process until an acceptable level of software quality is achieved. The progress of this type of process is not linear rather progress is a process of convergence towards an acceptable level of performance. Today, there is a strong movement in software projects (as well as projects with high uncertainty and ambiguity in scope) against the waterfall sequential process, and to accept these cycles, ensure continues testing, as proposed by agile methods. These types of processes cannot be adequately represented in Gantt Charts as it is simply not known *a priori* how often the loops have to be repeated.

Further, the Gantt Chart's Logic assumes that the project progress is measured linearly. Project controlling with Gantt Charts builds on the logic of linear effort behaviour, e.g. if a bar in the chart representing a project task is 50% elapsed then the status of the task execution is 50%. This is at odds particularly with the front-end of projects in drifting environment where projects converge into the development.

3.6 Summary of the Implications of the Gantt Chart's Logic to Project Management

Table 2 provides a summary of the arguments presented above. Gantt Charts could enhance the implementation process if a project is not very dynamic and faces situations of uncertainty. Many projects in the construction industry match these specific task characteristics. Often they are more or less routine projects with a low amount of innovativeness and uniqueness. Under these conditions efficiency is an important performance criterion and should be in the focus of the management process. But if projects are unique and highly innovative the determinism premise does not hold and a mechanistic approach will not lead to acceptable outcomes. Under these conditions uncertainty is likely and could only be overcome if the value proposition of the project is changed. This happens in an environment of multiple stakeholders with conflicting interests and objectives leading to political influences that destabilize a project's requirements and project success cannot be sufficiently described with achieving a deadline.

Table 2 here

4 Discussion, Conclusion and Outlook

In the analysis of the conceptual foundation of the Gantt Chart we identified six principles very much intertwined with Scientific Management as well as in the traditional project management mindset, which we term the Gantt Chart's Logic. We explored the implications to what we conceptualise as project, project management, project manager and success. As we explored each of the principles, we argued that these were made to a very different context (repetitive routine operations) in a different time (early 20th century) and have inherent limitations, but still are actually appropriate to certain project contexts, but definitely not all.

While the majority of the contemporary project management thinking already accepted that the assumptions of the Scientific Management are flatted, the practice is still pretty much embedded in this deterministic and mechanistic paradigm. One of the rare exceptions is the movement of Agile Project Management that directly addresses some of the limitations.

The analysis leads also to further research questions and alternative tools to visualize project plans and progress. In line with Whyte et al (2008), we have showed in the article that tools and images and intrinsically related to how we think about projects and manage them. Yet, there have been surprisingly few studies on what visual representations are used, how are they used, why and with what results. There is room for the development of other visualisation tools that are not based on flatted assumptions as the Gantt Chart.

In a more conceptual level, our analysis suggests a "fit" hypothesis between the use of Gantt Charts and its logic to manage projects in specific contexts only. Reflecting on the derived conditions it could well be that a misfit between the situation and the use of Gantt Charts could be a predictor of project failure. Further research could unravel a relation between project performance issues and the inappropriate use of Gantt Charts to plan and manage the implementation process.

Finally, this article shows that some of the logic embedded in project and project management has been borrowed from other contexts and applied to projects without deep understanding of the implications of this logic to projects. This calls for the development of a 'discipline of project management' with its own theories and thinkings, and careful application of theories and ideas that are not made for projects. Taken the high adoption of project-organising in standing organisations (Pettigrew, 2003), and that the current (general) management context is, so as projects are, recognised to be uncertain, dynamic and far more temporary than one would care to consider in the times of Scientific Management, project-driven theorising can contribute not only to the management of projects, but also to general management.

It is clear that Gantt Charts are representing a specific paradigm that could enhance or limit the implementation process of a project depending on the specific situation. By showing its roots, we hope to portray a caricature of project management and so with help practitioners and academics to understand its limitations, and, in Foucault's terms, 'free thought from what it silently thinks, and so enable it to think differently' (Foucault, 1971).

5 BOX 1: Life and work of Henry Lawrence Gantt

Henry Lawrence Gantt was borne in 1861 in Maryland in the fringes of the civil war. Gantt went to the McDonogh School, a free farm school for bright boys from poor families, where he became later a teacher in natural science and mechanics (what might explain his ground-breaking contributions to professional training and education). After graduating in mechanical engineering at Stevens Institute of Technology in 1884 (a year after Taylor), Gantt started his industrial career at the steel industry but maintained close contact with the school (Petersen, 1986). He joined the Midvale Steel Works, Philadelphia, where he met Taylor. Gantt became an advocate of the Scientific Management. He worked with Taylor for over a decade and his thoughts were influenced by the principles of rationality, determinism, optimisation promoted by Taylor. However, in 1901 the two broke up and Gantt became a consultant on his own. As Wren puts it:

> *"Gantt and Taylor were an usual team; they had mutual interests in their quest for science in management and developed a deep mutual admiration for each other's world. Gantt grasped the essence of Taylor's work and, though they clashed at times, became a prime disciple of Taylor" (Wren, 1987, pp. 133)*

Gantt had an impressive intellectual productivity, he has published over 150 titles and three major books: 'Works, Wages and Profits', 'Industrial Leadership' and 'Organizing for Work'. He also patented over twelve inventions, has made numerous presentations in the A.S.M.E. and lectures at Stevens, Columbia, Harvard and Yale. He is deemed to be one of the first successful management consultants. (Wren, 1979, pp. 160)[5].

Similar to Taylor, Gantt's key preoccupation was with 'economical utilisation of resources' and productivity through reward systems to motivate employees to work efficiently, scientific definition of work and selection of worker and fair division of wealth between employees and employees, what he termed the 'harmonious cooperation'. However, his ideas resembled a more human-centric management. His key contributions were in payment systems, visualisation and control tools, and the role of the management system to the society.

6 BOX 2: Principles of Taylorism

We refer throughout the article to Taylorism and its four principles. These are summarised below:

[5] More detail on Gantt's biography, see: Petersen (1986), Alford (1934), Rathe (1961) and Wren (1994).

- **Development of a true science of work**: "a science for each element of a man's work, which replaces the old rule-of-thumb method" (Taylor, 1911). With the science of work, there was clarity on the duration of tasks as well as on the process of how to execute the task, and so it was possible to set the *fair day's work* and avoid *systematic soldiering* and pressures against *rate busters*. It also allowed an increase in efficiency by designing *the best way* to do the task, and creating a context that reduces distractions, and turns organisations to machine and workers to machine parts
- **Scientific selection and progressive development of the worker**: "scientifically select and then train, teach, and develop the workman, whereas in the past he chose his own work and trained himself as best he could." (Taylor, 1911). It is possible to determine and select the best person for the job with the required mental and physical qualities, and train them so to execute the job following the prescribed method precisely
- **Bridging Scientific Management and Employee:** *"[Managers] heartily cooperate with the men so as to insure all of the work being done in accordance with the principles of the science which has been developed"* (Taylor, 1911). This involved an adequate **control and reward** systems
- **Co-operation between manager and worker:** ***"****There is an almost equal division of the work and the responsibility between the management and the workmen. The management take over all work for which they are better fitted than the workmen, while in the past almost all of the work and the greater part of the responsibility were thrown upon the men."* (Taylor, 1911). Productivity was a responsibility of **both managers and employees.**

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Figures

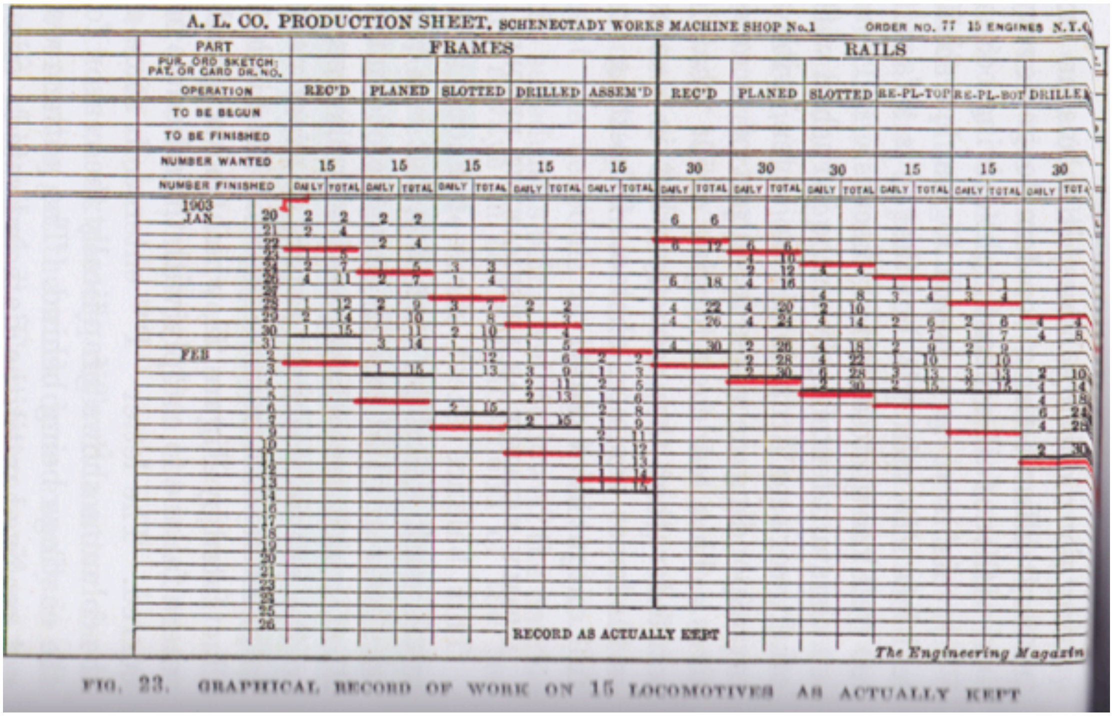

Figure 1: Early Version of the Gantt Chart
Source: Gantt (1916, pp. 276)

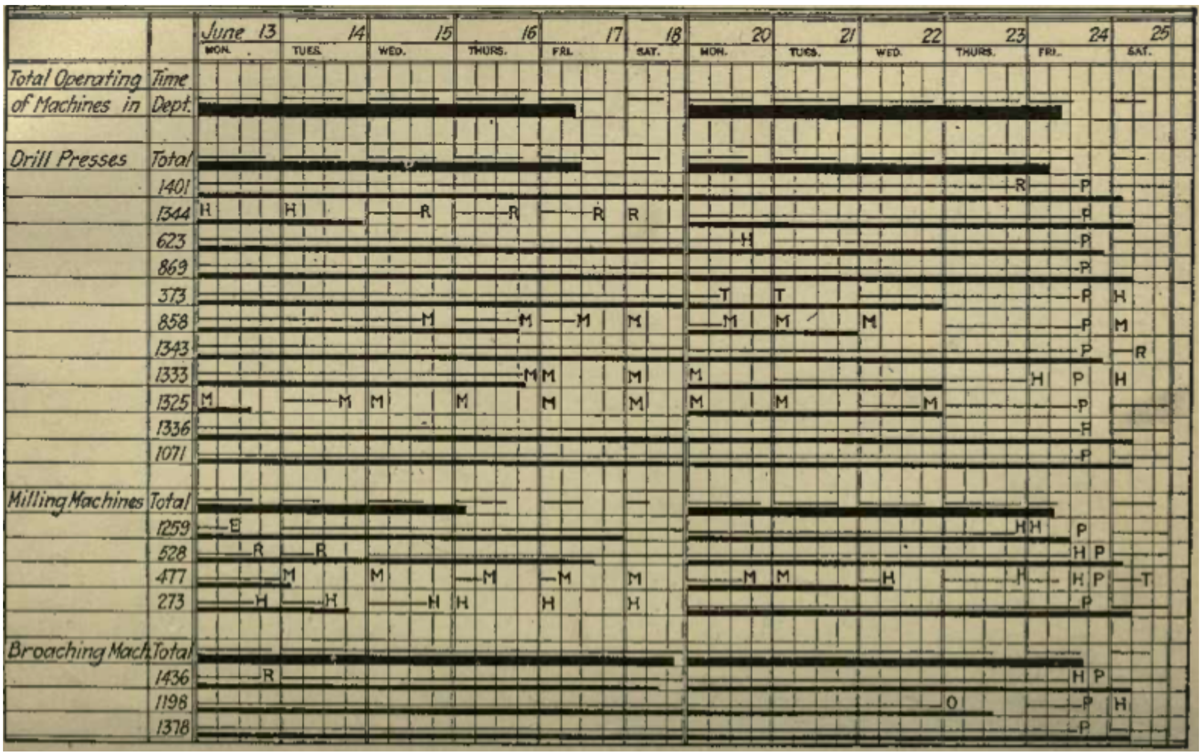

Figure 2: Gantt Chart as We know Today
Source: Clark (1922, pp. 24)

Tables

Table 1: Exploring Assumptions and Principles embedded of the current Use of the Gantt Chart

Steps	Implied assumptions	Principles
Define the activities: Breakdown the project scope and translate work packages into activities	• Scope can be translated into activities *a priori*	• Deterministic
	• There is *one* best way to execute the project	• Objective
	• There is clarity both in terms of scope and process	• Deterministic
	• The most appropriate way to do projects is by dividing it into activities	• Analytic
	• The whole is the sum of the parts	• Analytic
Define the sequence: identify and document the relationship between the tasks and define its sequence	• Type of dependency can be pre-defined and quantified in terms of time, e.g. AB SS+1	• Objective • Unidimensional
	• Task dependencies remain stable	• Deterministic
	• There is a clear and discrete interface between tasks	• Objective
	• Task execution is sequential only	• Sequential
	• Interfaces are defined and managed in terms of time and sequence, not content; pooled interfaces are discouraged	• Sequential • Unidimensional
Estimate activities resources[1], budget and durations	• It is possible to estimate the duration of each task with a high degree of certainty[2]	• Deterministic • Objective
	• Clear accountability to task execution could be defined[3]	• Accountable
Monitor the progress by comparing the actual work and the baseline	• Progress is sequential (Waterfall process), i.e. it follows a pre-defined order of what comes first and what comes later, and when a task is 'completed' it will not be revisited	• Sequential
	• Progress is measured against the completion of the tasks on time	• Unidimensional
	• Potential opportunities for alternative approaches to manage projects emerging during the project process are not exploited and discouraged	• Determinism
Document and manage changes to the baseline	• Potential issues that the project may face should have been identified *a priori*. The impact of 'truly' unknown-unknowns are not recognised, but instead recognised as lack of foresight.	• Deterministic
	• Management by minimising the gap: efficiency and effectiveness are the objective and achieved by 'sticking' to the plan. Change is avoided and should be mitigated.	• Deterministic • Unidimensional
Identify the reasons for delays and note in the Gantt Chart[4]	• It is possible to define the reason (or very limited number of reasons) to delays	• Deterministic • Objective • Accountable

[1] This activity implies that it is possible to define skills and knowledge necessary to manage each task a priori and therefore objectively define the 'best man for the job', a clear principle of scientific management. In Taylor's words "scientifically select and then train, teach, and develop the workman, whereas in the past he chose his own work and trained himself as best he could." (Taylor, 1911)

[2] One could argue that Gantt Chart, if used with tools such as PERT, could show pessimistic, optimistic and likely scenarios, and therefore consider the accuracy of the estimations. However, we still assume accuracy in the determination of the inaccuracy of the estimates.

[3] In the use of Gantt Chart the focus is on durations, however accountability is also implicit in the tool, and software such as MS Project express the resource accountable for the task in the Gantt Chart.

[4] This practice is no longer in use, but part of the original tool, as described in Section 2.

Table 2: Implications of the Gantt Chart Logic to Projects

	Implications of the Gantt Chart's Logic					
	Unidimensional	**Objective**	**Deterministic**	**Analytic**	**Accountable**	**Sequential**
General Definition	Focus on one dimension over others	There is one truth, one right way, and that can be determined.	It is possible to determine everything that will happen	Break a task into pieces. The whole is the sum of the parts	Clear definition of who is responsible for something or some action	Characterised by regular sequence
Principles in the context and mindset of the Scientific Management	Reduction of waste of human effort, maximise work that can be done in a given period of time	Systematically define what is the right task performance and the fair day's work	Task performance is detailed *a priori* in routine repetitive operations	Division of work, increase in efficiency, accountability and control over the execution of the task		Sequential manufacturing process
Principles in the current use of Gantt Chart - The Gantt Chart Logic	Visual control based on efficiency, work/time	Gantt Chart is the statement of reality, *the* best way to execute the project	It is possible to determine *the* scope and process *a priori*	Divide the work into tasks	Define who is responsible for each task	Linear sequence of activities in projects
Implications to:						
Project	Project is a process with clear start and finish	Project exists and can be defined *a priori*, independent from people enacting it	Project is about turning *the* plan into reality	Project is the sum of the tasks to be executed	-	-
Project Management	Managing through deadlines to meet pre-defined delivery date	Follow the Gantt Chart. Estimates are defined rationally, and progress reports are valid and reliable	Define *the* scope and process and execute it; avoid and manage the gap between plan and actual	Break down the scope, and transform it into tasks	Assign clear accountability to the different pieces of the project	Management through a waterfall project process. Projects progress linearly
Project Manager's Role	Make sure people deliver on time	Plan the best way to do the project and control progress against this baseline	Plan to avoid gaps between plan and actual, or at least identify and put project back on track	Ensure an optimal division of work Define roles and responsibilities, including of the PMer	Emphasise accountability over each task, and 'blame' those who fail to deliver	Ensure tasks are executed in the 'right' sequence, and each step is completed and freeze, so the project can move to the next
Success	Delivery on time	Meet the baseline…	… without surprises	Deliver every task…	… that one is accountable for	Right first time – no loops
Most appropriate Context	Time is the most important success criteria	Low uncertainty and behavioural complexity		Low complexity and interdependence	Clear scope and liner project progress	
Inherent	Need to balance several dimensions	Such conditions are rather rare in		Focus on low level delivery,	Cycles and 'convergence' to solutions	

Limitations	project contexts	individualistic behaviour, loosing sight of the project benefit	are discouraged

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Limitations	project contexts	individualistic behaviour, loosing sight of the project benefit	are discouraged