



Gantt charts: A centenary appreciation

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Abstract

With the proliferation of microcomputer based project management packages Gantt charts have enjoyed a revival in their use. Although Henry L. Gantt is recognized as their developer their origins and provenance are less well known. Gantt was a close associate of Frederick W. Taylor and an advocate of Scientific Management. His paper describing the use of “graphics” for general production planning appeared alongside Taylor’s *Shop Management* in 1903 and was an integral and critical component of Taylor’s system. Without Gantt’s charts to plan the workloads for men and machines both in departments and throughout the factory Taylor’s system would have been unworkable. The focus of this paper is to describe more fully their development and early history; and review their contemporary uses and future prospects.

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1. Introduction

The proliferation of microcomputer based project management packages has led to a revival in the use of Gantt charts. This popularity underscores their usefulness as a management tool. Although Henry L. Gantt is known as their developer their origins and provenance are less well understood. This explores the history of Gantt charts and their application to a wide range of planning problems beyond their current use in project management.

2. The origins

The origins of the Gantt chart are not well understood: Field and Keller (1998, p. 182), Mer-

edith and Mantel (1995, p. 354), and Nicholas (1990, p. 26) all note that Gantt charts originated with Gantt’s work during the First World War. Fogarty and Hoffmann (1983, p. 511) and Gido and Clements (1999, p. 194) vaguely date it to the early 1900s. Even Petersen (1991) does not describe the differences between Gantt’s various “charts” as they evolved. Wren (1994) notes that a “breakthrough” came during the war, but does not discuss its nature or significance. Contemporaries such as Alford (1924, p. 180) discuss various uses for Gantt charts without placing any emphasis on their use for projects. Gantt charts were very well established by the mid-1920s as a general production planning tool; with a peripheral and all but ignored use in managing projects.

Gantt (1903, p. 1322) first described a version of his charts in an article published alongside Frederick W. Taylor’s *Shop Management* paper (Taylor, 1903, p. 1337). The two were to be considered

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jointly as an integrated production planning and control system. Taylor later published Shop Management in book form (Taylor, 1919) without Gantt's article. Thus, Gantt's work on production planning is not as well known as Taylor's work. Gantt charts were developed contemporaneously with Taylor's system, and date from 1890 (Gantt, 1903, p. 1326). Although Gantt described his daily balance as "graphical" it should be considered a "tabular" approach since no graph was used.

In their initial incarnation Gantt charts were a production planning tool used to plan and manage batch production. In modern terms Gantt used a time-phased dependent demand approach to production planning. Gantt's production planning worked in a "top-down" manner by linking end-item requirements to their constituent components with time-phased production to allow all components to be available when needed for subsequent production activity. These due dates were further used to plan daily production by determining the quantities to be made and then tracking production against the daily goals. As Gantt noted,

proper planning and control involved: "... two sets of balances: one of what each workman should do and did do; the other, of the amount of work to be done and is done" (1903, p. 1323). This table would then show exactly what was delivered against the plan and would highlight any discrepancies for remedial action. This basic planning tool was the genesis of Gantt's later developments.

Fig. 1 (Gantt, 1903, Fig. 290, inserted after p. 1325) shows one of Gantt's "balance sheets and schedules". It identifies the items to be produced, the number to be done each day and in total; and the date when production was to start and finish. Although the sequence of operations was not explicitly described, the start and end dates did so implicitly. The factory was sales-driven with its operations directly linked to customer orders, there were no intermediate inventories to buffer production and lot-for-lot ordering policies were used. This represents a "lean" approach to production.

Gantt also specifically noted production problems on these sheets—in the example shown the

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H. L. GANTT.

FOUNDRY PRODUCTION SHEET.

ORDER NO. 83
8 ENGINES D. L. & W.

A. L. CO. SCENECTADY WORKS.

PART.	BELL STAND.		EXHAUST PIPE.		TENDER FRAME CENTER PIN.		ENGINE TRUCK SWING BOLSTER.		GRATE BAR.		GRATE SIDE.		GRATE SIDE.		ASH PAN END.		ASH PAN SIDE.		GRATE FRAME SUPP.		GRATE BAR.		
	PATTERN NO.	17,212	17,939	16,927	16,907	19,458	18,953	18,954	21,343	21,341	18,950	18,961											
PATTERN DUE.	2-3	2-2	2-2	2-2	2-2	2-2	2-2	2-2	2-2	2-2	2-2	2-2	2-2	2-2	2-2	2-2	2-2	2-2	2-2	2-2	2-2	2-2	
PATTERN REC'D.	1-22	1-22	2-6	2-4	2-8	2-10	2-10	2-10	2-10	2-10	2-14	2-14											
NO. WANTED PER DAY.	1	1	1	1	8	2	2	1	1	1	1	1											
TOTAL NO. WANTED.	8	8	8	8	64	16	16	8	8	8	8	8											
NUMBER MOULDED.	Daily	Total	Daily	Total	Daily	Total	Daily	Total	Daily	Total	Daily	Total	Daily	Total	Daily	Total	Daily	Total	Daily	Total	Daily	Total	
1908 FEB.	2																						
3			1	1																			
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7	7		1	5																			
8			2	7	2	2	1	2	P														
9			2	7	2	2	1	2	P														
10							1	3	3	3	1	P	1	1	P	1	P	P					
11	4	4					1	4	8	10	2	3	2	3	1	1							
12	1	2	5	1	8	2	4	1	5	7	2	5	1	4	1	4	2	3					
13					3	7	1	6			2	6	2	6	1	2	3	3					
14	1	6					1	7	8	18	1	7	1	7					P	P			
15							1	8	1	8	1	8	1	8	2	4	1	4	3	3	2	2	
16	2	8					1	8	1	8	1	8	1	8	2	4	1	4	3	3	2	2	
17									1	8	24	1	9	1	9	2	6		4	7	2	4	
18									1	8	30	1	10	1	10	2	8	2	6	1	8	12	5
19									1	8	37	2	12	2	12			2	5			1	5
20									1	8	45	2	14	2	14								
21									1	8	53	2	16	2	16								
22									1	7	59											1	6
23																						1	7
24									5	64												1	8
25																							
26																							

Begin moulding not later than date opposite upper heavy line. Finish at date opposite lower heavy line.

THIS IS A PORTION OF AN ORDER SHOWING HOW THE RECORDS WERE ACTUALLY KEPT. THE FIGURES IN ITALICS REPRESENT CONDEMNATIONS. THEY ARE USUALLY ENTERED IN RED INK.

Fig. 1. A balance sheet and schedule for a foundry.

“*P*” observed in some columns denotes difficulties in obtaining the patterns needed to start production. This theme continued with later charts so that production problems were identified with assignable causes wherever possible, as later “quality” management approaches would come to appreciate. The intimate relationship between planning, monitoring work against plan and subsequent control action was directly represented on the chart.

3. A general production planning tool for scientifically managed factories

Taylor and Gantt realized that although work study could save effort, contemporary planning and control systems would generally waste these savings. They recognized that achieving “local” optima with individual tasks was necessary but insufficient to achieve “global” productivity improvements. The key to improving overall productivity lay in developing comprehensive planning systems. The creation of a method to plan and control individual operations was the indispensable first step. These local plans could then be integrated into a larger system. Gantt’s approach allowed foremen to coordinate their work with that of other departments, and this harmonization was thought to be the “strongest proof” of its value. The purpose of Gantt charts then was not local optimization but as part of a broader scheme to manage the planning and control throughout the factory.

It has since become evident with materials requirements planning that an uncapacitated production planning system will yield unworkable results when used in a capacitated environment. So too for Taylor’s Planning Office, and Gantt charts were the remedy. Gantt’s charts resolved a singular difficulty: the factory-wide machine loading problem. Clark describes how Gantt charts helped meet customer service objectives:

If a promise of a delivery is to be kept, all the work in a plant must be planned so accurately that when a new order is received, it is possible to tell almost to a day when the work will

be completed. 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).

Several points from this quotation are notable:

1. The whole production process was considered since “all the work” was planned and controlled. The Gantt charts were intended to be a comprehensive plan for the whole factory over the whole of its planning horizon.
2. The “all the promises” shows that the factory was sales driven. The process was based on a “solution” procedure in which the plan was “constructed” with new sales orders fit in around existing commitments. This approach was easier than the alternative process that would schedule all orders to develop an overall optimum when a new order was received.
3. A schedule accurate “almost to a day” implies precise planning and control. Work in progress inventories had to be kept small to ease planning and facilitate shop floor management. Large buffer stocks might allow higher utilization rates, but would make the coordination of workflows more vague.

Gantt charts were applied in real production environments, with multiple products competing for capacity on multiple machines spread over a sequence of processing operations across several manufacturing departments involving people whose commitment to the schedule was a concern. In this complex environment the charts were found to work reasonably well and to be the most effective solution. They endured as “best practice” for decades, and evolved as Porter (1929) and Alford (1945) show their adaptation to increasingly varied production environments.

Gantt charts were used to coordinate activities so orders would flow smoothly through the factory while keeping machines and staff busy. There was no mechanism for trying to optimize operations, and that problem was thought too complex for

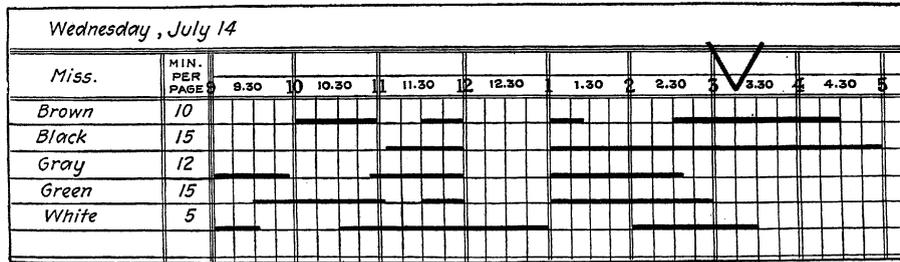


Fig. 2. The layout chart for a Stenographic Department.

solution. MacNeice (1951, p. 130) describes an experiment in which a group of 300 management students that included many practicing production managers were given a shop scheduling problem and asked to solve it intuitively. Only three people were able to do so; but, when provided with Gantt charts, virtually all were able to develop effective solutions in only 15 min.

Gantt charts were so useful that applications proliferated. The original incarnation (Gantt, 1903; Clark, 1925) of Gantt charts was to manage machine and man loading. Man record charts (Fig. 12, Clark, 1925, p. 34–35) would show the work accomplished each day by each worker in comparison with amount that should have been done. Similarly the machine record chart (Fig. 8, Clark, 1925, p. 18–19) would show the utilization of machine tools in a factory relative to the available capacity.

A key feature of Gantt charts was its focus on *systemic* rather than algorithmic solutions to utilization problems. If capacity was over-loaded a variety of solutions might be sought. The stimulus to develop more efficient operations was plain. Gantt recognized that facility “capacity” was a flexible concept and that manual planning could readily accommodate “fuzzy” constraints. Conversely, problems with under-loaded work centres were to be resolved by marketing the products made in those work centers; or by reducing their capacity if such demand management was not feasible.

Charts showed managers the progress of an order as it moved between work centers and the time planned for each. These were described as “layout charts”. A simple example for a single

department is shown in Fig. 2 (Fig. 15, Clark, 1925, p. 46) that describes the control of a secretarial pool’s work under irregular demand conditions. As Clark notes:

... it is necessary to distribute them (letters to be typed) evenly over the available stenographers so that one will not be loaded up ... while another sits waiting. If the capacity of the whole stenographic department is taken up for the day ... it is impossible to get any more work that day unless he (the originator of the correspondence) prefers to have left over to the next day some of the letters he has already dictated (Clark, 1925, p. 47).

These allowed the best and most equitable utilization of the workforce; the differing capabilities of the typists were recognized in planning workloads. All staff would work as required by the changing demands, when it was slack they might finish early, when it was heavy they might have to work until quitting time; and if demand were particularly heavy some of it would be displaced to later periods. Where the stenographic department dealt with hours and days, other departments in more complex, industrial environments might focus on days and weeks, and machine centers rather than individuals.

Layout charts for machine shops (Fig. 16, Clark, 1925, p. 48–49) are notable for two differences from the stenographic example. First, they deal with specific production orders- each is individually planned and its progress monitored. Second, is their identification of the causes of any difficulties.

Layout charts complemented by “load charts” that described the capacity utilized in future periods (Fig. 24, Clark, 1925, p. 66–67). These could show whether the workloads were balanced across machines or departments. There were two applications: first, in scheduling, i.e., shifting orders so that the best capacity utilization could be achieved. Second, in throughput management, i.e., to indicate “bottlenecks” where improvements would increase throughput for the whole factory. This accords well with Goldratt and Cox’s (1992) OPT technique’s focus on bottleneck work centers—in the short term they need to be planned around; and, in the longer term, increasing throughput in some manner needs to be considered.

In Gantt’s perspective the production planning and scheduling problem was one aspect of a broader problem in maximizing the factory’s productivity and ability to service its customers. These were not mechanistic tools or algorithms but aids for managers to make informed decisions.

4. Early applications of Gantt charts to projects

Project management was one minor use for Gantt charts. Alford (1924, p. 180), comments that charts: “. . . may be equally valuable when applied to things less concrete . . . as planning special investigations, and the undertaking of special projects.” In discussing operation scheduling for ship building Kimball (1925, p. 149–150) discusses operation scheduling for ship building suggests that “a similar master schedule can be made for each and every large element entering into constructing a ship . . .” and goes on in the next section of his book to say: “it is not uncommon to chart all important events for all work on the master schedule . . . The Gantt chart is perhaps the most effective form of such graphical schedules” (Kimball, 1925, p. 152). However, none of these actually show a Gantt chart for a project. Even much later authors such as Moore (1951) and MacNeice (1951, p. 57) comment on the usefulness of Gantt charts for managing projects but do not show how one might be constructed or used. The earliest illustration of a project based Gantt chart found by

the author is in Koepke (1941, Fig. 3, p. 391) who cites Kimball and Kimball (1939) (though it is not in the first edition, Kimball, 1925) as its source.

It seems very unlikely that Gantt used charts as presently constructed in 1917. Alford (1918), Provost (1961, p. 63) remarks: “as Gantt realized, the number of rivets driven . . . was a better than fair index to the percentage completion of the ship.” and he goes on to suggest that project progress reports would be outdated by the time they were received. Alford comments: “. . . he (Gantt) perfected the Gantt chart as a managerial tool, selected ‘rivets driven’ as the unit by which to measure progress (emphasis added) in the building of ships . . .” (Alford, 1934, p. 192) It seems that Gantt did not use his charts as do modern project managers do; and, the implications of these remarks is that Gantt may have rejected such a mode of use.

5. Stagnation and decline

In the inter-war years Gantt’s charts were very popular. Their great advantages were their simplicity and ease of understanding. However, paper based charts were unwieldy however and many companies produced planning boards as a method for implementing them. Alford (1945) shows several, and production management books show boards used for creating and updating charts. Nevertheless, major difficulties arose in using the charts due to limitations in information handling. Buffa (1961, p. 108) observes: “even with the mechanical boards the problem of maintenance is considerable . . . and this often results in discarding any attempt at the close control implied by the charts.” Buffa (1961, p. 108) speculated that computers that could identify the best schedules by trial-and-error methods would replace Gantt charts.

Gantt charts required data collection and planning effort that was not worthwhile in organizations for whom uncapacitated approaches to production planning were workable. Factories that operated near full capacity potentially could benefit (Moore, 1951, p. 235) from using Gantt charts for capacity management; but the difficulties of introducing and applying them in such

environments were significant. The 1950s and 1960s were the era when Gantt charts fell out of favor for their original applications- the complexities of large scale production were recognized as too great for the technique.

6. Operational research innovations and project management

The perceived shortcomings in Gantt charts were not a stimulus for the development of network-based project planning methods. Articles by Kelley and Walker (1989) and Fazar (1962) show that desires to use operational research in conjunction with the first computers were a prime consideration, and no mention of Gantt charts is made. In the mid-1960s discussions of project management begin to deal with both networks and Gantt charts, but until then there was a clear division between operational researchers that discuss network methods and the operations management literature. Only in the latter 1960s do production management texts such as Moore (1965) and Buffa (1969) deal with projects. Previous editions did not consider projects, but the advent of the Critical Path Method brought an expansion of interest in that area. The use of Gantt charts as a complementary method for project planning and management then became more prominent. The rise of computers and network methods provided Gantt charts with a reprieve, and the subsequent development of microcomputing and its stimulation of personal-computer based project management packages has revived Gantt charts.

7. Gantt charts for project management and micro-computers

Gantt charts have seen a revival in their popularity. They provide a quick and easily understood means for describing project activities and this attraction has stimulated their use in microcomputer based project management packages. All major packages (Levine, 1986; PM Network, 1995) allow users to present their results in the form of Gantt charts. While network methods are used to

determine schedules and critical activities the associated diagrams are not easily produced. The Gantt chart displays are readily programmed and may be easily presented in a variety of formats useful for managers. The activities may be listed readily in order of entry, by start date or criticality/slack; and appropriate “bar” graphics showing the start, duration, finish and possibly slack may be easily placed on the display or printed page. The activities are specified in the chart’s two dimensions: the vertical axis identifies the activity, while the horizontal axis defines its placement in time. Activities are easily positioned, with their histograms indicating significant data such as start and finish times, and with color signifying important time issues such as activity criticality, slack, in progress, completed, late/past due, etc. so that the chart is most useful tool. In contrast, the placing of an activity within the display of a network diagram is complex. Precedence relationships constrain its positioning; and aesthetics make it difficult to automate the construction of a network. Even the representation activities as nodes or arrows is not universally resolved. Information on activity duration, start and finish times, and slack would also be text based if presented, and there are few conventions for their display. The Gantt chart is a simpler tool for software developers to implement and for users to interpret in providing the maximum information in the most comprehensible format.

8. Gantt charts in interactive applications

The popularity of Gantt charts in project management has seemingly stimulated their use in other areas, particularly where displaying information about schedules is important. In some cases these represent a return to applications that were once in favor. Truscott and Cho (1987) apply Gantt charts to scheduling batch production through multiple work centers. Although they focus only on lot-splitting, this is the sort of problem for which Gantt developed his charts. Wennink and Salvendy (1996) look at general planning applications of Gantt charts for scheduling and develop a planning board generator as a

management decision support system. Similar applications in job shop scheduling may be seen in Jones and Maxwell (1986), Viviers (1983), Hancock (1988), Rogers (1989) and Davis and Kanet (1997); and for flexible flow lines in Kochar et al. (1988). These all use Gantt charts as a tool to facilitate involving people in scheduling. Such charts may increase the acceptance of algorithm-based solutions by allowing people to test the effectiveness of solutions themselves. Charts may also provide very effective tools to allow users to create and evaluate schedules manually; with good solutions to complex problems; much as MacNeice (1951) observed. Goldratt (1988), Holloway and Nelson (1973), Jones and Maxwell (1986), Pruett and Schartner (1993), Schmahl and Anand (1994) and Kunst (1999) have found such interaction found beneficial.

Gantt charts are useful for displaying schedules, whether produced manually or through some heuristic or optimizing algorithm. In these cases the benefits follow from their effectiveness in presenting a great deal of information (what jobs run, when, on which machines, and for how long, and where idleness or congestion occurs). The method is highly adaptable and can readily focus on issues that concern managers. Gantt charts are not solution techniques but they facilitate communications between the analyst and user, and provide a powerful method for implementing interactive approaches to scheduling.

9. Summary

Gantt charts remain popular management tools in spite of dating back over a century. In their current primary application to projects they provide an effective means for displaying important information. Their earlier applications to more general production planning and control problems have been overwhelmed by practical problems and overtaken by technological developments. Computing offers more powerful techniques for modeling these problems; but Gantt charts still have found a role providing a readily useful interface allowing users to define problems and better understand and accept solutions.

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