Calculating Hourly Cost Rates In Project-Based Industries – Part 1: capacity modeling

Jan Emblemsvag
Norwegian University of Science and Technology
Gary Cokins
Global Advisor

Abstract: Hourly cost rates are crucial in project costing due to the substantial proportion of labor costs in projects. Critical in this endeavor is to model capacity correctly. While there is much published on capacity modeling, there is nothing published about capacity modeling in project-based industries. This fact in combination with the fact that it is a contentious topic in corporations makes it an important topic for research. Therefore, in this paper capacity modeling is analyzed and a revised version of the CAM-I capacity model is proposed for project-based industries. Both an example and a case are provided to allow detailed discussions.

Keywords: Earned Value, Activity-Based Costing, subcontracting, shipbuilding, construction, fabrication.

1 Frame of reference

Never ask for money spent
Where the spender thinks it went
Nobody was ever meant
To remember or invent
What he did with every cent. (Robert Frost - The Hardship of Accounting)

Projects frequently have a dismal success rate. For example, The United States Government Accountability Office performed a study of 778 major Information Technology (IT) projects performed in the fiscal year 2008 by the 24 major agencies of the US Government. The findings were typical of many IT projects – 53% of these projects (413 projects) totaling 25.2 billion USD in the fiscal year 2008 where either poorly planned (79%), poorly performed (15%) or both (6%) (Powner 2008). When looking at so-called 'mega-projects', the performance is even worse, see (Flyvbjerg *et al.* 2012). Here, cost overruns are 1400% and even more, and delays are in years.

Thus, the need to improve project cost management has been emphasized by several over the years including (Jorgensen and Wallace 2000) and (Kinsella 2002). Methods and approaches have therefore been steadily improved. The most recognized, and possibly one of the most useful and meaningful approach to report status and to analyze project cost, schedule, and performance, is the Earned Value Management (EVM) method (Sumara and Goodpasture 1997); see (Fleming and Koppelman 2005) for an excellent overview. However, as all approaches and methods, this approach requires the input of correct information to provide insights and good decision support. This input includes basic cost elements such as hourly cost rates.

In EVM, costs are reported/analyzed via the Cost Breakdown Structure (CBS), and it consists of the traditional cost elements such as materials, labor, and overhead support expenses, see (Fleming and Koppelman 2005). Overhead costs are commonly allocated projects based on the number of labor hours. The result is that the hourly cost rate will consist of direct costs and well as overhead costs so that the cost simply becomes the number of direct labor hours multiplied by the hourly cost rate. Thus, costs become a function of materials and labor in project costing. Since materials are a direct cost that is easy to measure, the focus is on the labor part in this paper. This is also where there is much discussion in practice.

Interestingly, the literature review in Part 2 finds that the calculation of hourly cost rates is a topic virtually without academic discourse. This is, of course, one reason why so many people calculate the hourly cost rate erroneously – it has simply not been a topic of neither academic research, teachings nor discourse of practice. Indeed, many textbooks in schools and universities alike are not up to date as to how capacity should be modeled, see (McNair and Vangermeersch 1998).

Due to the complexity of calculating hourly cost rates as a topic, we chose to publish in two parts where the second part will deal with the hourly cost rates. Here, in Part 1, we must first have a thorough discussion concerning a major component of calculating hourly cost rates – modeling the capacity. This is a foundation for the discussion in Part 2.

Interestingly, the literature on capacity modeling is blank as to project-based industries – we have at least not been able to find a single discussion of projects and capacity other than the trivial concerning having enough people in projects. For example, the (IMA 1996) guideline only mentions the word ‘project’ in three instances and all are related to a project of implementing their guidelines for corporations. Also, the excellent review of capacity management by (McNair and Vangermeersch 1998) is without any discussions related to project-based industries. This is particularly interesting since there is an increase in the number of corporations that work in project-based ways, see for example (Kerzner 2013; Morris *et al.* 2013). Hence, before we can address the issue of calculating hourly cost rates in project-based industries, we must address capacity modeling, which is the purpose of this part.

The first step is to understand the context better for project-based industries since we argue it requires a different approach to capacity modeling than what is the current best practice. There are peculiarities that must be understood, which is discussed next in Section 1.1. This will enable us to pose research questions in Section 1.1. Then, in Section 2, the literature on capacity modeling is reviewed so that an approach for capacity modeling for project-based industries can be found in Section 4. Before that, however, a basic example is provided in Section 3 to illustrate the discussion so far. In Section 5, a case is presented from project-based industries. The closure is provided in Section 6.

1.1 The peculiarities of project-based industries concerning capacity management

In project-based industries, we have no standard costs because essentially little is based on repetitive processes. This general lack of industrialization has resulted in poor productivity development. In fact, the construction industry is the industry with the least productivity improvement in the past 20 years, according to McKinsey, with just 1% improvement per year in the global average of the value-added per hour, which is roughly a quarter of manufacturing (The Economist 2017). One of the reasons is that the volatility of this industry has curbed investments to the advantage of manpower. With no capital-intensive approach, but rather a manning-intensive approach, consolidation of the industry has also been lacking.

In project-based industries capacity is thought to be added to the project either from a line management department or by being dedicated to the project through own resources or external contractors (subcontractors), see (Fleming and Koppelman 2005). That is, they typically follow the ‘Flexing’ organization approach in **Figure 1**. This is a satisfactory assumption from a project management point of view because the finance function must provide the cost data for these project resources after which EVM can be calculated including baselines, actual cost, etc.

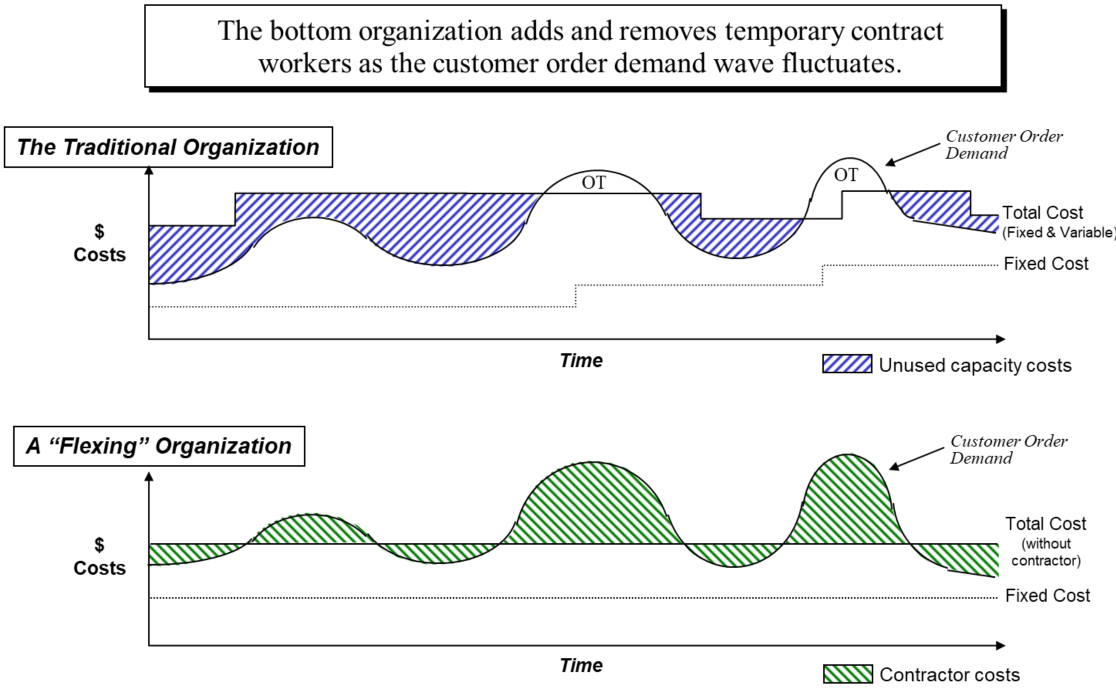

Figure 1 – How project-based industries flex their organization to cope with demand. Copyright © 2004: Gary Cokins, SAS Institute.

However, if we assume the overarching corporate view, we realize that project-based industries also share resources and have overhead costs, but these issues are not captured in EVM or any other project management approach unless it is captured in the hourly cost rate. Herein, may lie the root to the problem this paper addresses – the project management function sees idle capacity and hourly cost rates as something beyond themselves, while the finance function works according to conventional methods discussed previously assuming that capacity is managed by the project. In short, the finance function and the project management function assume the other handles what they do not handle themselves. This is a situation avoided in industries such as manufacturing where all resources are mostly in-house or procured on a regular basis. The 'flexing' of the organization takes a much longer time for which capacity models can be adjusted irrespective of which approach is being used.

Therefore, the situation for project-based industries must be discussed further, and for the sake of simplicity, it is beneficial to separate projects into three categories:

1) <u>Small projects</u> embedded in the line organization. Here we find basically all types of smaller projects such as improvement projects, smaller IT projects, and smaller product development projects.
2) <u>Medium-sized projects</u> outside the line organization but often formed in a matrix organization. These projects are typically found in construction, fabrication, shipbuilding and professional consultancies of various sorts where resources are owned by the line but

temporarily moved into a project organization working on a specific contract. These industries are also highly cyclical, and this is mostly solved using subcontractors.

3) Large projects with their own, complete organization. These are projects that cost billions involving civil construction, large IT projects and the megaprojects. Common for all of them is that they are so large that they are treated as standalone entities also organizationally.

Depending on which type of projects we talk about, we typically find three approaches to capacity management. Small projects typically obtain all their capacity from the line organization, and since they are small in numbers they are usually manned by line-organized people. Sometimes, they hire an outside consultant or two or ten and use some subcontractors, but the bulk of the work is carried out internally by people that report to a line manager. Since capacity is provided like this, the hourly cost rate they should use is the same as the rest of the corporation depending on what departments the people come from. This is well-captured in existing literature such as (Cokins 2001) where he uses the CAM-I capacity model as a basis. Calculating the hourly cost rates correctly will, therefore, take place automatically in the ABC system. Hence, this paper will not discuss such small projects in any further detail.

On the opposite spectrum, we have large projects. Since these projects are large, cost assignment becomes trivial – all costs belong to the project – except some small amount of overhead costs from corporate headquarters which will essentially be dwarfed by the project cost. Consequently, such projects are also of no interest to this paper. This means that both the small and very large projects have approaches that work well today, such as the CAM-I capacity model. Unfortunately, as demonstrated earlier, this is little known among corporations today.

However, for medium-sized projects typically found in shipbuilding, fabrication, and construction the situation is different. While it is common that every corporation and industry argues that they are unique and special, even in manufacturing claims of uniqueness abound (Plossl 1991), some *do* have some peculiarities enough to warrant adaptations of tools, approaches and methods from other industries.

The Lean Construction community has naturally focused on the construction industry, and (Nam and Tatum 1988; Warszawski 1990) have identified four peculiarities for the construction industry that sets it apart from manufacturing.

1. One-of-a-kind nature of projects.
2. Site production (the product is produced where it will be used).
3. Temporary multi-organization.
4. Regulatory intervention.

These peculiarities largely explain why construction work becomes extra complex and uncertain (Koskela 1992). See **Table 1** for more information. The four peculiarities that (Koskela

1992) mentions also apply to shipbuilding albeit to various degrees, see (Emblemsvåg 2014b) for more details.

Table 1 – Construction peculiarities, their problems, and solutions. Source: (Koskela 1992).

Peculiarity	Process control[1] problem	Process improvement[2] problem	Structural solution	Operational solutions for control	Operational solutions for improvement
One-of-a-kind	• No prototype cycles • Unsystematic client input • Coordination of uncertain activities	• One-of-a-kind processes do not repeat, thus long-term improvement questionable	• Minimize the one-of-a-kind content in the project	• Upfront requirements analysis • Set up artificial cycles • Buffer uncertain tasks	• Enhance the flexibility of products and services to cover a wider variety of needs • Gather feedback information from earlier projects
Site production	• External uncertainties: weather, etc. • Internal uncertainties and complexities: flow inter-dependencies, changing layout, the variability of productivity of manual work	• Difficulty in transferring improvement across sites solely in procedures and skills	• Minimize the activities of the site in any material flow	• Use enclosures etc. for eliminating external uncertainty • Detailed and continuous planning • Multi-skilled work teams	• Enhance planning and risk analysis capability • Systematized work procedures
Temporary organization	• Internal uncertainties: exchange of information across organization borders (flow disconnects)	• Difficulty in stimulating and accumulating improvement across organization borders	• Minimize temporary organizational interfaces (inter-dependencies)	• Team-building during the project	• Integrated flows through partnerships

[1] Process control refers to the management of a project.
[2] Process improvement refers to the development efforts of the permanent organization in construction (designing, manufacturing of materials and components, contracting).

Regulatory intervention	• External uncertainty: approval delay			• Compression of the approval cycle • Self-inspection	

Shipbuilding, however, has a fifth peculiarity as also alluded to by the (LeaderSHIP 2015 High-Level Advisory Group 2003). Ships have a very high technical complexity which in combination with the importance of offering short delivery times, resulting in almost every ship (except the simplest, highly standardized ones) being partly produced concurrently while procurement and engineering are ongoing processes, well before all engineering issues are solved – thus, we are talking about Concurrent Engineering Procurement and Construction (EPC) (Emblemsvåg 2014b). This adds extra complexity and uncertainty during project execution often solved through the usage of Variation Orders (VO) and subcontracting and/or delayed contractual delivery.

In sum, project-based industries have peculiarities that warrant adaptations concerning capacity management and ultimately calculation of the hourly cost rates as well as discussed in Part 2. As the review so far shows, there are currently no identified published material on this topic. With that in mind, we can formulate the research questions and the hypotheses next.

1.2 Research Question and Hypothesis

We have so far demonstrated that conventional approaches are deficient. They fail to distinguish between the supply and demand for capacity. They model capacity incorrectly. Thus, incorrect amounts of overhead costs are assigned, and the hourly cost rates become miscalculated. Then, the research question logically becomes:

How should capacity be correctly modeled in project-based industries with medium-sized projects?

Based on the discussion so far, including the review to come in Section 2, ABC is considered the proper approach for calculating the hourly cost rate correctly. Hence, we hypothesize:

A revised CAM-I capacity model provides the best basis for calculating hourly cost rates correctly in project-based industries where the projects are of medium-size.

This hypothesis will be tested through inductive reasoning in the context of action research and the literature. We will explore the possible approaches found in the literature, discuss their merits and issues, identify how it can be improved and apply it in a case. From this, we will establish the correct approach towards modeling the capacity in project-based industries with medium-sized projects. In Part 2, this provides the foundation for the correct calculation of the hourly cost rates.

Before we come that far we provide a literature review in Section 2 to demonstrate that capacity modeling is a contentious topic academically, treated in outdated modes, and incorrectly treated in project-based industries. Then, in Section 3, an adjusted version of the CAM-I model is presented which will be tested in the subsequent sections.

2 ON CAPACITY MODELING

In their guideline on practice in cost management, the (IMA 1996) states flat out that;

> *This guideline is based on the underlying belief that capacity, and capacity cost management, is an essentially elusive concept. No single tool or a single view of capacity cost management is best. No single, magical capacity number will work in all companies, all settings or all decision contexts. Rather, an overall philosophy or approach to capacity supports a company's efforts to improve performance through better management and utilization of its resources.*

Hence, the topic of capacity cannot be treated as one-way fits all, and nowhere is this perhaps clearer than in project management – an area that the Institute of Management Accountants (IMA) and others have not made any significant advances into as mentioned earlier. This said, we believe that project-based industries have much to learn from non-project-related industries such as manufacturing because they have been studying the topic since the early 1900s when the topic first was explored, see (IMA 1996). Two directions were discussed back then (McNair and Vangermeersch 1998):

1. Henry Gantt was the leading authority that argued that the cost of excess- and idle capacity should not be included (i.e., capitalized) in the inventory asset cost of a product or service but had to be written off as an expense to the income statement at the end of the year. In this way, the products carried only the costs they incurred and not the costs of large factories with greater capacity than required, poor and inefficient utilization of machinery, etc.
2. Alexander Hamilton Church, an early luminary cost accountant, did not disagree with the main thrust of Gantt's argument, but he disagreed with Gantt as to where to place costs of excess- and idle capacity on the financial statements. Ultimately, he would charge it back to the product via a supplemental rate. In later years, he changed his opinion and agreed with Gantt because the supplemental rate ultimately led to products absorbing all costs including excess- and idle capacity.

Before continuing, some definitions are required to make the remaining discussions meaningful. There are several types of capacity, and these are (McNair and Vangermeersch 1998):

1. Theoretical capacity – this is the highest level of work a process or plant can complete using a 24/7 operation with zero-waste. This is denoted 100% capacity and represents an ideal operation. Some, such as (Stedry 1960), have argued that using this standard is demotivating

while some corporations, such as Motorola and Hewlett-Packard, are using it to drive continuous improvement. Another benefit of using theoretical capacity is that cost estimates will be stable and reliable.

2. Practical capacity – this is the theoretical capacity adjusted for the nonproductive time required for maintenance, set-ups and an allowance for breakdowns. As such, it builds some waste into the cost management system. As a rule of thumb, practical capacity is 80% to 85% of theoretical capacity, according to (Kaplan and Anderson 2005).
3. Normal capacity – this is the average, expected capacity utilization over a defined period of time. This lower than practical capacity, and a very general range, according to (Keller 1958), is that normal capacity constitutes 65% - 85% of practical capacity.
4. Budgeted capacity – this is simply the capacity that the budget is based on.
5. Actual capacity utilization – this is the capacity utilized. Typically, this varies a lot.

Interestingly, nobody at the time suggested the approach that is used by most corporations today, that is, using the budget capacity for cost management. The argument was that this approach was illogical and indefensible because it would lead to a full cost absorption to products irrespective of capacity utilization. In fact, this idea was open for ridicule, belonging to 'feeble-minded' people, in the long and thorough discussions in the 1920s and early 1930s.

So, why did corporations end up with the approach mostly used today? The answer is politics, as explained in great detail by (McNair and Vangermeersch 1998). With capacity utilization in the 1930s, even prior to the depression, being very low something had to be done. In fact, (Martin 1932) reports numbers as low as 12%-40% (20% average) in steelworks, 30%-40% in the textile industry, 60% in the paper industry and all others industries operate between 18%-60%. The politician that intervened in the USA was Franklin D. Roosevelt who enacted the National Industrial Recovery Act (NIRA), better known as New Deal. NIRA introduced principles such as cost-plus pricing, uniform costing and excess capacity that required excess costs be recovered through increased costs and prices (full cost absorption). "For the first time in history, cost accounting had become law", as (Taggart 1934) notes.

Corporations that signed on to the New Deal were awarded a Blue Eagle insignia showing that they patriotically supported the recovery of America. Citizens in the USA were asked to buy from these corporations and boycott the rest. Even though the Supreme Court ruled the NIRA as unconstitutional in 1935, the two years in which it operated undid all the good work concerning capacity management done prior to 1932. Indeed, during these 2 years, more than 600 cost codes were developed and implemented and they lived on to this day after the Supreme Court ruling as did the idea of full cost recovery through full cost absorption to products.

The Security Exchange Acts of 1933 and 1934 actively reinforced this in an effort to ensure the validity of external financial reporting through the auditing process (McNair and Vangermeersch 1998). In so doing, accounting shifted its focus from serving and supporting management with information for insights and decisions to external financial reporting for compliance with government regulatory agencies. A way to think of this is the purpose of external financial reporting is for "financial valuation" (e.g. product inventory) whereas, in contrast, the purpose of internal management accounting is for "creating financial value" for shareholders and owners.

Other acts cemented this, even more, acts such as the Federal Wage and Hour Act, the Miller-Tydings Act and the Robinson-Patman Act. In 1940 a seminal monograph, (Paton and Littleton 1940), was published that continues to shape GAAP today both through how accounting is taught and practiced today. In it, they essentially said that excess and idle costs should be attached to the production of products.

From 1979, an increasing number of people started to question this approach. Unfortunately, in 1987 the Internal Revenue Services (IRS) in the US specified that practical capacity could no longer be used for tax purposes (Horngren and Foster 1991), i.e. for product inventory valuation in balance sheets and costs of goods sold (COGS) in income statements. Corporations had to use the master-budget volume (the anticipated level of capacity utilization for the coming budgeting period) and not practical capacity, which was used from 1975 – 1987.

There is nothing (including GAAP), however, that prevents corporations from using two co-existing accounting systems – one for management purposes abiding by local Managerially Accepted Accounting Principles (MAAP) and one for external reporting purposes abiding by GAAP. However, due to the economies of recordkeeping and the desire for simplicity (and arguably for convenience), corporations use the same approach for both purposes (Horngren and Foster 1991). So, the idea of having an hourly cost rate for external reporting purposes and one for internal, managerial purposes would unlikely to take place. Yet, this is required to manage capacity correctly because the only defensible capacity models are based on either theoretical capacity or practical capacity (McNair and Vangermeersch 1998).

In later years, (Cooper and Kaplan 1992) have revived the discussion (Soperiwala 2006) with their work on Activity-Based Costing (ABC), and in 1996 the Statement on Management Accounting (SMA) issued by Institute of Management Accountants in the US and Society of Management Accountants in Canada following a joint research project where 12 different approaches were discussed, made it abundantly clear (SMA 4Y 1996):

> *Management accountants need to reopen the debate of "best practice" in capacity cost management – debates which led to elaborate idle capacity reporting practices early in this century. Management accountants need to recognize and address current misconceptions about GAAP and its implications for capacity reporting practices, and openly search for ways to better reflect economic reality in their reporting practices.*
>
> *Where they will be effective, major changes in common reporting practices required to support capacity cost measurement include:*
>
> - *Use of theoretical rather than annual budgeted capacity as the capacity baseline measure.*

- *Elimination of idle capacity costs from product costs*...
- *Analysis and reporting of the cost of capacity in different states of preparedness.*
- *Reporting of all idle, nonproductive and productive uses of capacity and their costs-*

This means that most corporations today are at odds with best practices. This paper will naturally be based on best practices as expressed by (SMA 4Y 1996). There is, however, no single best practice – it is context-dependent – and there is nothing discussed anywhere how project-based industries should approach the challenge. So far there have been two main streams in the quest of developing more useful capacity models since the 90s (Soperiwala 2006).

One is led by (Ostrenga 1988) who has argued that the cost of used- and idle capacities should be determined at the machine, shift, and plant levels, respectively. Consequently, fixed capacity costs are split into machine-, shift-, and plant-related costs and then divided by the practical capacities of machines, shifts, and plants to determine the unit level fixed cost at each hierarchical level. While this may sound realistic on paper and undoubtedly provide an accurate approach, the authors of this paper believe that this will also be an impractical approach as there are many more levels in a corporation than those three to consider if we go down that avenue.

Hence, in general, we subscribe to the next approach – the CAM-I (Consortium for Advanced Manufacturing – International) Capacity Model. Also, this model is implemented through a series of templates that form the backbone of the capacity cost management database (IMA 1996), which can be advantageous for corporations for benchmarking by using standardized definitions to assure comparability. The CAM-I Capacity Model focuses on how capacity is used and classifications for when it is idle. To do so, it goes further than the first approach. It separates rated capacity into productive and non-productive capacity, and idle capacity, see **Figure 2**.

Rated Capacity	Summary Model	Industry Specific Model	Strategy Specific Model	Traditional Model
Rated Capacity	Idle	Not Marketable	Excess Not Usable	Theoretical
		Off Limits	Management Policy	
			Contractual	
			Legal	
		Marketable	Idle But Usable	Practical
	Non-productive	Standby	Process Balance	Scheduled
			Variability	
		Waste	Scrap Rework Yield Loss	
		Maintenance	Scheduled Unscheduled	
		Setups	Time Volume Change-Over	
	Productive	Process Development		
		Product Development		
		Good Products		

Figure 2 – The CAM-I Capacity Model. Source: Cam-I, 1995.

These capacities are split further. For the purpose of this paper, we stay at the summary level because calculating hourly cost rates cannot be done at a too granular level to be practical for usage in projects. The definitions of these levels are nevertheless important, see (IMA 1996):

1. Idle capacity: Capacity not currently scheduled for use. The CAM-I Model breaks idle capacity into three specific classes: not marketable (no market exists or management made a strategic decision to exit the market), off-limits (capacity unavailable for use) and marketable (a market exists but capacity is idle).
2. Non-productive capacity: Capacity not in a productive state or not in one of the defined idle states. Non-productive capacity includes setups, maintenance standby, scheduled downtime, unscheduled downtime, rework and scrap. Variability is the primary cause of non-productive capacity.
3. Productive capacity: Capacity that provides value to the customer. Productive capacity is used to change a product or provide a service. Productive capacity results in the delivery of good products or services. It may also represent the use of the capacity for process or product development.

Because of its structure, the CAM-I Capacity Model offers several key features that most corporations should find useful. It integrates capacity data across many dimensions; it ties and reconciles to the costs in the financial reporting system; it details responsibility for capacity losses, and it uses time duration as a unifying measure (IMA 1996). In terms of improving the economics of a corporation, the process is as shown in **Figure 3**. We see that we should convert non-productive capacity to idle capacity (arrow A), after which the idle capacity should be either converted to productive capacity (arrow B) or reduced (arrow C).

These two main streams can naturally be combined, as showed by (Soperiwala 2006). It should be noted that there are other more specialized capacity models as well, such as CUBES developed by (Konopka 1995) in the context of high capital expenditures and short product life-cycles, such as in the semiconductor industry. However, the authors of this paper find more advanced approaches too premature when most of the project-based industries cannot handle any of the two more basic approaches. Indeed, manufacturers were on average using less than 73% of their capacity (Uchitelle 2003), and with such numbers, there is plenty of opportunity for improvement before utilizing more advanced methods.

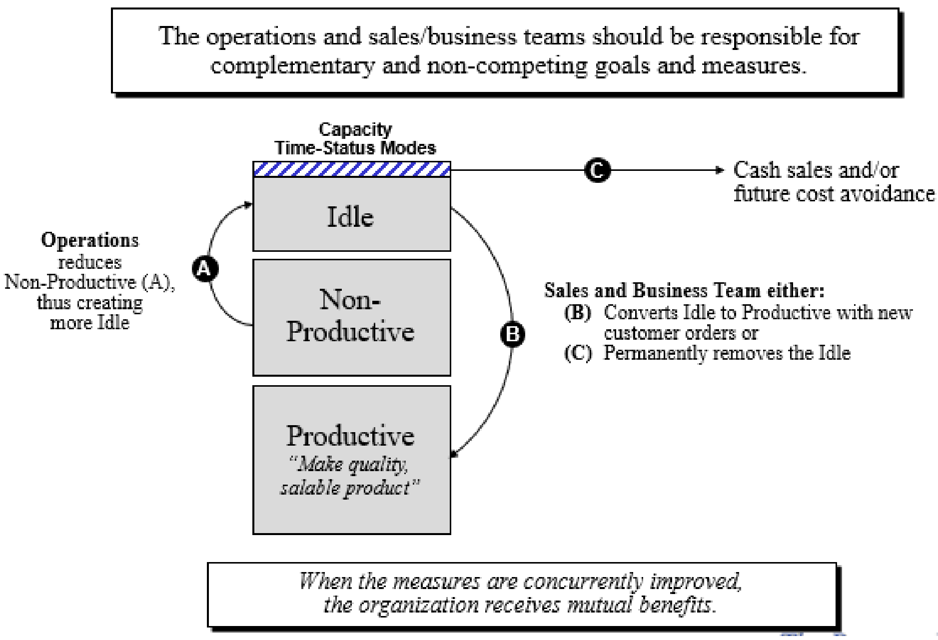

Figure 3 – **Improving the economics using the CAM-I Capacity Model.** Copyright © 2004: Gary Cokins, SAS Institute.

Interestingly, none of the publications we have reviewed discuss the capacity management of project-based industries. However, for the purpose of this paper, we use the CAM-I model and definitions because it is the best starting point we have identified. It should be noted that if we remove the elements of the CAM-I Capacity Model that are difficult to exercise in a project-based industry, except for advanced practitioners, we end up with a model similar to the Supplemental Rate Method initially developed in the early 1900s by A.H. Church. This approach is depicted in **Figure 4**.

Indeed, (IMA 1996) notes that the "…approach differs from conventional accounting practice in its adherence to practical capacity as its baseline capacity measure; most conventional accounting systems use budgeted capacity for this purpose". If used correctly, it should not degrade into full cost absorption, which is what Church witnessed and therefore ultimately rejected the method on behavioral grounds, see (McNair and Vangermeersch 1998).

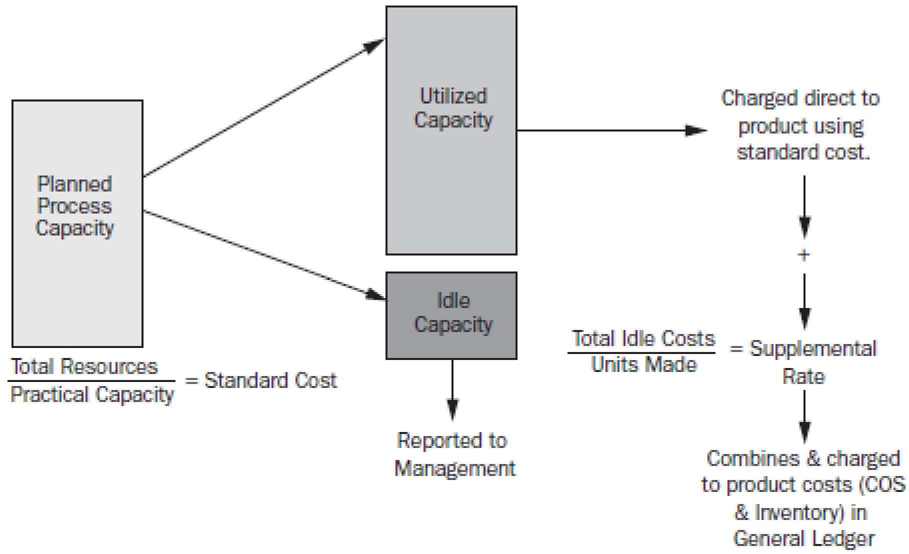

Figure 4 – The Supplemental Rate Method (IMA 1996).

Since a degraded variant of the Supplemental Rate Method forms the basis for conventional accounting practices, we will illustrate next how the apparently small difference between using practical capacity and budgetary capacity plays out for determining unit costs over a budgetary period.

3 Illustrating conventional- versus correct capacity modeling in a basic example

Assume we have a machine that performs two different jobs – A and B – as illustrated in **Figure 5**. Since Job A has a budgetary demand of 30% of the capacity and Job B has a budgetary demand of 55% of the capacity, there is 15% idle capacity compared to the maximum practical capacity. With no demand, this idle capacity has currently no economic value. The questions are "What is the cost of Job A and the cost of Job B?"

Before we address these questions, two key concepts in economic theory must be introduced and defined to further build the case – the supply of capacity and the demand for capacity and the differences between measures of expenses and costs. A useful and succinct definition, in our opinion, is provided by (Cooper 1990) when he writes that;

'Cost' is a measure of resource consumption that related to the demand for jobs to be done whereas 'expense' is a measure of spending that investigates the capacity provided to do a job.

To clarify, expenses are when an organization exchanges money by paying a supplier, contractor, or employee by writing checks, paying invoices and the like using the currency that exits in the treasury. In contrast, all costs are *calculated*. Examples are a process cost, an activity cost (in ABC), a product or service-line cost, a project cost, a customer cost, or the cost of any cost object you like.

This begets the question; should we calculate the cost of the jobs allocating costs based on budgetary demand, or should we calculate the costs according to maximum practical capacity (total supply of capacity)? Many argue that since we have to carry the machine expenses anyway, they would like to distribute the expense of the machine between the jobs according to their budgetary demand on the machine, i.e., calculate the jobs based on budget. This is the conventional accounting practice discussed earlier in this paper, based on GAAP, done by countless corporations, and described by (IMA 1996).

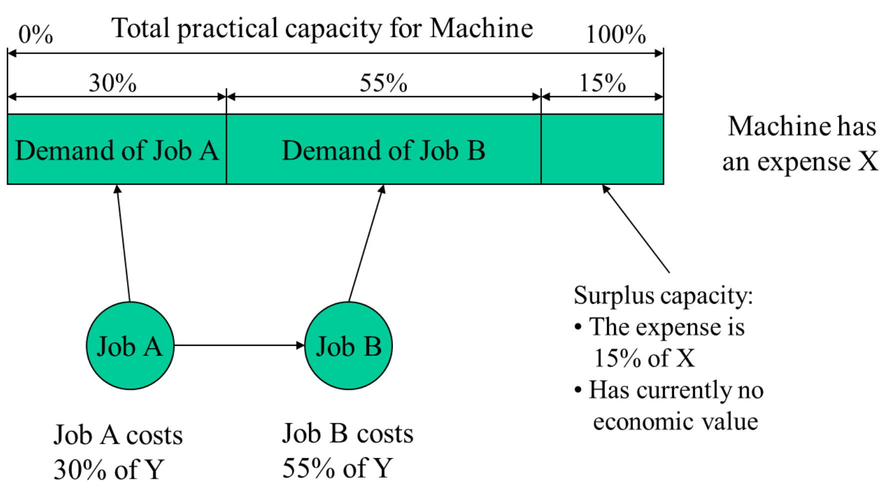

Figure 5 – A single machine performing two jobs.

Assume that the 1) direct operating expense is 10,000 USD/year, 2) total practical capacity is 1,500 hours per year, 3) Job A consumes 450 hours per year and 4) Job B consumes 825 hours per year. Then, the cost estimates become as shown in **Table 2**. Since Job A and Job B essentially split the machine expenses according to their budgetary demand, then Job A costs 3,529 USD and Job B must by default cost the remaining 10,000 – 3,529 = 6,471 USD. In other words, the idle capacity issue is ignored.

This conventional accounting practice introduces some fundamental problems readily observable in this simple example including only direct expenses. First, the surplus capacity of 225 hours is smeared out like butter across bread, as it were, onto Jobs A and B making both jobs appearing more expensive than what they really are. This is at odds with a fundamental principle in cost management that cost objects should carry their own costs to prevent cross-subsidies because we build in waste – we create a 'hidden factory', as (Miller and Vollmann 1985) called it. This is dangerous when you must win work in a highly competitive market.

Second, the cost of the jobs will vary according to demand. The lower the demand, the higher costs and *vice versa*. As (Horngren and Foster 1991) assert in the context of product costing – this is in contrast to good business judgment. Thus, this approach is fundamentally wrong, flawed, and dangerous. Therefore, a correct way – such as the CAM-I approach – must be investigated. In this simple example, it becomes similar to the Supplemental Rate Method because we have no non-productive capacity.

Table 2 – Calculating job costs for the machine example.

Traditional	Demand	Dir. Expences	Overhead costs	Total costs
Job A	450	3 529	1 588	5 118
Job B	825	6 471	2 912	9 382
S U M	**1 275**	**10 000**	**4 500**	**14 500**
Hourly rate		7,84	3,53	11,37
ABC	**Demand**	**Dir. Expences**	**Overhead costs**	**Total costs**
Job A	450	3 000	1 350	4 350
Job B	825	5 500	2 475	7 975
Surplus capacity	225	1 500	675	2 175
S U M	**1 500**	**10 000**	**4 500**	**14 500**
Hourly rate		6,67	3,00	9,67
Comparison of rates		**17,6 %**	**17,6 %**	**17,6 %**

The first thing to notice using this approach is that the amount of capacity must be estimated – knowing the demand for the individual jobs suffices no longer. We need to know the maximum practical capacity to estimate the idle capacity. For a single machine, this is relatively easy and intuitive, and it is 225 hours per year in this example. The main challenge of estimating the capacity – even for a machine where it is relatively easy – is that the maximum practical capacity is often significantly lower than the theoretical capacity and it is fluid, i.e., depending on issues such as maintenance frequencies, product mix and more. However, as discussed before, the maximum practical capacity should be used. As a rule of thumb, maximum practical capacity can be set to 80% to 85% of theoretical capacity (Kaplan and Anderson 2005). What is important is to be approximately right and not exactly wrong, i.e., we pursue relevance over numerical accuracy.

With Job A demanding 30% of the maximum practical capacity, the cost becomes 3000 USD. Similarly, for Job B it becomes 5500 USD. The cost of the idle capacity becomes 1500 USD. This is

17.6% lower cost estimate than using the conventional approach! In many cases, this would be a highly significant change in the margin and hence the ability to win contracts.

With a different capacity modeling, the hourly cost rates change as well. This means that each hour now costs 6.67 USD/hr compared to 7.84 USD/hr under the conventional approach. The difference is again 17.6%. Even in this simple example, we can see that there is a significant impact on the hourly cost rate.

Corporations often want the hourly cost rates, the topic of Part 2, to include overhead costs (in addition to the direct cost such as wages, social costs, and protective equipment, etc.) for cost management purposes (Eden and Ronen 1991). In project-based industries, it is extensively used for estimating the costs of contracts, variation orders of contracts and more. The same example is therefore expanded to include overhead costs in the hourly cost rate for the sake of completeness. This will be discussed thoroughly in Part 2 to which the interested reader is referred.

Suppose that the machine has 4500 USD in overhead costs per year. With a capacity of 1500 hours, this means that each hour should be assigned 3 USD/hr in overhead costs if we calculate correctly. Job A will, including overhead costs, therefore cost 4,350 USD, and Job B will consequently cost 7,975 USD all-inclusive. The surplus capacity will be assigned 675 USD in overhead costs, which will give a total cost of 2,175 USD. The sum of all costs will naturally be 14,500 USD as expected.

Using the conventional approach, we get very different results. Since only 1,275 hours are in demand, the overhead cost rate will become 3.53 USD/hr. The overhead costs for Job A will now rise from 1,350 USD to 1,588 USD giving an increase in total costs for Job A from 4,350 USD to 4,588 USD. Everything will appear 17.6% more expensive than what is real. Corporations working like this will be at a real and noticeable disadvantage.

Clearly, the correct approach allows not only logical cost estimates of the jobs but also the costs of the capacity and hence facilitates questions concerning capacity; we can *manage* the capacity. This is the correct way. Management must match the supply of capacity to demand and not the other way around (Cooper 1990).

In project-based industries, there is a final issue to grapple with – the fact that often there is a substantial amount of subcontracted work. In this simple example, there is no such complexities and in manufacturing subcontracted work is essentially procured component parts. This is discussed more next to identify a capacity model that will work for project-based industries.

4 The CAM-I model for projects

When adjusting the CAM-I Capacity Model it is crucial to realize that while manufacturing and similar industries sell products and services that are predefined, i.e., developed before being offered to the customers. In Fabrication, Shipbuilding, and Construction, however, the product is delivered as a project, see (Emblemsvåg 2014b, a), through a collaborative process between customer and supplier. This has several implications:

1. Idle capacity consists of only two types – marketable capacity and not marketable capacity. The latter is due to capacity imbalances in cases where capacity constraints apply because they cannot be resolved using subcontracting. An example from shipbuilding could be a dry-dock large enough for 2 ships that is occupied by a small vessel. Due to the stage in the project – for example, the hull is open – the dry-dock cannot allow any docking of other vessels for some weeks. Hence, a significant portion of the dry-dock capacity is not marketable. If such capacity constraints do not apply, then all idle capacity is in principle marketable due to the possibility of subcontracting work either externally to the project or use subcontractors in the project.
2. The non-productive capacity is quite different from the CAM-I Capacity Model. This is because yield losses, standby, and setups are treated as a part of reality in project execution and normally never tracked. Maintenance, scrap and rework are often tracked, however. It may be surprising to find Research & Development (R&D) and process improvement as non-productive capacity, but this is because in project-based industries such activities are much riskier than elsewhere since the scope of work changes from contract to contract. Furthermore, they often remove capacity from productive capacity hitting both the revenues side as well as the cost side. This may help explain the poor state of productivity improvement in these industries compared to manufacturing – it is basically too risky for most except the most advanced corporations who established themselves as industry leaders.
3. Productive capacity is what contributes towards the projects through project execution, but it can at times also include process development not directly warranted by the scope of the project but profitable enough to be performed and paid-off through the project execution of the project at hand.

Thus, we propose an adjusted version of the CAM-I Capacity Model, as presented in **Figure 6**, for project-based industries where the projects are of medium size, as defined earlier. With respect to cost management, the model in Figure 5 yields the same result as the CAM-I Capacity Model. We should use maximum practical capacity, which is normally larger than the utilized capacity in the Supplemental Rate Method particularly as it has been used since 1987, as discussed earlier.

<table>
<tr><th>Rated Capacity</th><th>Model Summary</th><th>Industry Specific Model</th><th>Strategy Specific Model</th><th>Traditional Model</th></tr>
<tr><td rowspan="9">Rated Capacity</td><td rowspan="2">Idle</td><td>Not Marketable</td><td>Capacity Imbalance due to Project Portfolio Mix</td><td>Theoretical</td></tr>
<tr><td>Marketable</td><td>Idle, but Usable</td><td>Practical</td></tr>
<tr><td rowspan="5">Non-productive</td><td>Research & Development</td><td></td><td rowspan="7">Scheduled</td></tr>
<tr><td>Process Development</td><td></td></tr>
<tr><td>Maintenance</td><td></td></tr>
<tr><td rowspan="2">Waste</td><td>Scrap</td></tr>
<tr><td>Rework</td></tr>
<tr><td rowspan="2">Productive</td><td>Immediate Process Development</td><td></td></tr>
<tr><td>Project Execution</td><td></td></tr>
</table>

Figure 6 – CAM-I Capacity Model adjusted for project-based industries.

Next, we will put our findings together in a discussion over an approach and a real-life case to illustrate the approach, and also point out that our proposed capacity modeling for project-based industries is a major improvement over today's practices and theories.

5 AN APPROACH TO DETERMINE CAPACITY IN PROJECT-BASED INDUSTRIES

The basic premise of cost management is to strike the right balance between relevance and accuracy – it is better to be approximately right than exactly wrong, as quipped by (Kaplan and Cooper 1999). This is nowhere more important to keep in mind than in project-based industries as they are characterized by a large number of uncertainties and random variations, see (Koskela 1992) for an excellent discussion.

A key issue will, therefore, be in how the capacity issue is handled. Recall from Section 3 how capacity was handled. That context was manufacturing, but the topic of this paper is projects where there is often a substantial amount of subcontracted work. The advantage of manufacturing is stationary work with largely fixed manning (at least in the short term). In project-based industries, however, the maximum practical capacity becomes more fluid since a significant portion of the scope of work is subcontracted – and hence capacity is difficult to assess.

In Part 2, we will investigate the two types of subcontracting arrangements – subcontracting by the hour and fixed-price enterprises – as they have implications for the cost management. In terms of capacity modeling, there is little difference – they key is to not mix sourcing decisions and contract arrangements into capacity management. A man is a man regardless of the contract in terms of capacity management.

For instance, in Table 2 we see an example that could apply to many corporations in project-based industries. The corporation has some capacity of its own and then it has subcontractors on its premises that do the rest of the scope of work. This is common in various types of fabrication/construction and shipbuilding as they are all site-based and use a temporary workforce in addition to their own, see (Emblemsvåg 2014b). Note that HSEQ is a common abbreviation for the Health, Safety, the Environment and Quality function.

From **Table 2** we calculate that the demand for hours compared to maximum practical capacity is 52%. In other words, there is 48% idle capacity. Since more than half the total capacity is subcontracted, such a number may come as a surprise. After all, why not scale down the subcontracting to demand? The answer is twofold.

First, in site-based projects with subcontracting, such as shipbuilding, it is not the manning that is the capacity limitation but the physical characteristics of the site. Determining the maximum practical capacity is, therefore, a function of how much manning the site can handle for a given overhead costs structure including management costs, facility costs and other overhead costs and not the manning of the current project portfolio *per se*. As (McNair and Vangermeersch 1998) say, there is no one size fits all in capacity management, and in this case, we see that it is the site that determines the capacity.

Second, there can be significant variations within weeks, months and quarters rendering fixed capacity employment impossible to ramp up and down accordingly. In this way, this case resembles manufacturing but unlike manufacturing the production is project-based and the volume fluctuates significantly. If maximum practical capacity was determined by the current project portfolio, the hourly cost rate would fluctuate accordingly, lack of demand would mean higher hourly cost rate and greater difficulty in selling new projects, whereas when there is a sufficient portfolio it will be easier to sell new projects. This is a self-fulfilling prophecy. Furthermore, such an approach would 1) fail to identify the cost of available capacity related to the site overhead such as facility, management and other overhead costs and 2) create fluctuating costs for two identical projects if they are executed under a different project portfolio *ceteris paribus*. This is explicated in Part 2.

Table 2 – Illustrative example of capacity in corporations having projects with subcontractors.

	Net own capacity [h]	External capacity [h]	Sum [h]	Demand [h]	Over-capacity [h]
Engineering	15 030	4 500	19 530	10 500	9 030
Production, workers	62 625	55 000	117 625	83 300	34 325
Production, other	9 500	1 500	11 000	7 000	4 000
HSEQ	8 000		8 000	6 500	1 500
Project management	4 500	500	5 000	4 500	500
Sum	**99 655**	**61 500**	**161 155**	**111 800**	**49 355**

Since determining the maximum practical capacity for such cases is fluid, it goes without saying that there is also associated with uncertainty. Therefore, some conservatism should be exercised when determining the maximum practical capacity.

We have now discussed demand, capacity and handling overhead to such an extent that we can accept the research hypothesis. In short, we have established an approach based on three steps:

1. Determine maximum practical capacity. The key is to identify which factors are limiting the amount of work that can be done without changing the overhead cost structure. There can be many such factors;
    a. The capacity of the site in terms of manning.
    b. The nature of the activities in the projects limiting the maximum manning that can be applied.
    c. Large machine centers.
    d. Space.
2. Determine demand based on the project portfolio.
3. Integrate the findings from steps 1 and 2 into a high-level capacity model as outlined in Section 4 to estimate the maximum practical capacity and idle capacity.

In Part 2, see (Emblemsvåg and Cokins 2020), the discussions of this paper, Part 1, will be integrated into a cost management system so that hourly cost rates can be correctly calculated.

6 Closure

The calculation of hourly cost rates consists of two major lines – correct capacity modeling and correct handling of overhead costs. We have so far attended the capacity modeling part. Based on the discussion we ended up with a revised version of the I-CAM Capacity Model designed for project-based industries where the projects are of medium size. In Part 2, we will introduce

Activity-Based Costing to handle the overhead costs, which will allow us to correctly calculate the hourly cost rates.

7 Acknowledgement

The authors would like to express their gratitude towards all those practitioners that have given examples to discuss over the years.

References

Cokins, G. (2001). Activity-Based Cost Management: An Executive's Guide. Hoboken, NJ, Wiley.p. 386.

Cooper, R. (1990). "Explicating the Logic of ABC." Management Accounting (UK)(November):pp. 58 - 60.

Cooper, R. and R. S. Kaplan (1992). "Activity-Based Systems: Measuring the Costs of Resource Usage." Accounting Horizons(September):pp. 1-13.

Eden, Y. and B. Ronen (1991). "The Hourly Rate: Myth and Reality." Industrial Management **33**(September/October):pp. 28-30.

Emblemsvåg, J. (2014a). "Lean project planning: Using lean principles in project planning." International Journal of Construction Project Management **6**(2):pp. 185-207.

Emblemsvåg, J. (2014b). "Lean project planning in Shipbuilding." Journal of Ship Production and Design **30**(2):pp. 79-88.

Emblemsvåg, J. and G. Cokins (2020). "Calculating hourly cost rates in project-based industries – part 2; cost management." The Journal of Modern Project Management. **8** (1): pp. X-Y.

Fleming, Q. W. and J. M. Koppelman (2005). Earned Value Project Management. Newtown Square, PA, Project Management Institute.p. 232.

Flyvbjerg, B., N. Bruzelius and W. Rothengatter (2012). Megaprojects and risk: An Anatomy of Ambition. Cambridge, Cambridge University Press.p. 207.

Fox, R. (1986). "Cost Accounting: Asset or Liability." Journal of Accounting and EDP(Winter):pp. 31 - 37.

Goldratt, E. M. (1983). Cost Accounting Number One Enemy of Productivity. Proceeding of APICS Conference.

Horngren, C. T. and G. Foster (1991). Cost Accounting: A Managerial Emphasis. Englewood Cliffs, NJ, Prentice-Hall, Inc.p. 964.

IMA (1996). Measuring the Cost of Capacity. Practice of Management Accounting. Montvale, NJ, Institute of Management Accountants (IMA).p. 35.

Johnson, H. T. and R. S. Kaplan (1987). Relevance Lost: The Rise and Fall of Management Accounting. Boston, MA, Harvard Business School Press.p. 269.

Jorgensen, T. and S. W. Wallace (2000). "Improving Cost Estimation by Taking into Account Managerial Flexibility." European Journal of Operational Research **127**(2):pp. 239-251.

Kaplan, R. S. (1984). "Yesterday's Accounting Undermines Production." Harvard Business Review(July/August):pp. 95 - 101.

Kaplan, R. S. and R. Cooper (1999). Cost & Effect: Using Integrated Cost Systems to Drive Profitability and Performance. Boston, MA, Harvard Business School Press,.p. 357.

Kaplan, R. S. and S. R. Anderson (2005). "Rethinking Activity-Based Costing." Research & Ideas - Harvard Business School Working Knowledge(Jan 24).

Keller, I. W. (1958). "Capacity Utilization Studies for Cost Control and Reduction." NAA Bulletin **39**(No. 11 (July)):pp. 38-45.

Kerzner, H. (2013). Project Management: A Systems Approach to Planning, Scheduling, and Controlling. Hoboken, NJ, John Wiley & Sons.p. 1296.

Kinsella, S. M. (2002). "Activity Based Costing: Does It Warrant Inclusion in A Guide to the Project Management Body of Knowledge (PMBOK Guide)?" Project Management Journal **33**(2):pp. 49-56.

Konopka, J. M. (1995). "Capacity utilization bottleneck efficiency systems - CUBES." IEEE Transactions on Components, Packaging, and Manufacturing Technology **18**(3):pp. 484-491.

Koskela, L. (1992). Application of the New Production Philosophy to Construction. Standford, CA, Stanford University, Center for Integrated Facility Engineering.p. 75.

LeaderSHIP 2015 High Level Advisory Group (2003). LeaderSHIP 2012: Defining the Future of the European Shipbuilding and Shiprepair Industry. Brussels, European Commission.p. 40.

Martin, R. F. (1932). "Industrial Overcapacity." Bulletin for the Taylor Society(June):pp. 94-99.

McNair, C. J. and R. Vangermeersch (1998). Total Capacity Management: Optimizing at the Operational, Tactical, and Strategic Levels. Boca Raton, FL, St. Lucie Press.p. 352.

Miller, J. G. and T. E. Vollmann (1985). "The Hidden Factory." Harvard Business Review(September-October):pp. 142-150.

Morris, P. W., J. K. Pinto and J. Söderlund (2013). Introduction - Towards the third wave of project management. The Oxford Handbook of Project Management. P. W. Morris, J. K. Pinto*et al*. Oxford, Oxford University Press**:**pp. 1-36.

Nam, C. H. and C. B. Tatum (1988). "Major characteristic of constructed products and resulting limitations of constructuon technology." Construction Management and Economics **6**(2):pp. 133-148.

Ostrenga, M. R. (1988). "A Methodology for Identifying Your Excess Capacity Costs." Journal of Cost Management(Summer):pp. 39-44.

Paton, W. A. and A. Littleton (1940). An Introduction to Corporate Accounting Standards. Chicago, American Accounting Association.p. 156.

Plossl, G. W. (1991). Managing in the New World of Manufacturing: How Companies Can Improve Operations to Compete Globally. Englewood Cliffs, NJ.p. 189.

Powner, D. A. (2008). OMB And Agencies Need to Improve Planning, Management, and Oversight of Projects Totaling Billions of Dollars. Washington DC, United States Government Accountability Office (GAO).p. 50.

SMA 4Y (1996). Measuring the Cost of Capacity. Practise of Management Accounting. Montvale, NJ, Institute of Management Accountants.p. 35.

Soperiwala, P. R. (2006). "Capacity Utilization: Using the CAM-I Capacity Model in a Multi-Hierarchical Manufacturing Environment." Management Accounting Quarterly **7**(2):pp. 17-34.

Stedry, A. C. (1960). Budget Control and Cost Behavior. Englewood Cliffs, NJ, Prentice-Hall.p. 182.

Sumara, J. and J. Goodpasture (1997). Earned Value - The Next Generation - A Practical Application for Commercial Projects. Project Management Institute 28th Annual Seminars & Symposium. Chicago, IL, Project Management Institute**:**pp. 13-17.

Taggart, H. F. (1934). "The Relation of a Cost Accountant to the NRA Codes." Accounting Review **9**(2 (June)):pp. 149-157.
The Economist (2017). Least improved. The Economist. **424:**pp. 47-48.
Uchitelle, L. (2003). Overcapacity Stalls New Jobs. The New York Times (web version), October 19th**:**pp.
Warszawski, A. (1990). Industrialization and Robotics in Building: A Managerial Approach. New York, Harper & Row.p. 466.

About Authors

Jan Emblemsvåg is the General Manager of Midsund Bruk AS, a leading supplier of pressure vessels and a fully owned subsidiary by National Oilwell Varco. He is also Professor II at Norwegian University of Science and Technology, consultant and speaker. His experience includes management consulting, project-, risk- and operations management and senior management positions in various industries. He is an ambassador to Quality & Risk Norway. He has written several books and dozens of papers. He holds a PhD and M.Sc. at Georgia Institute of Technology and a M.Sc. at Norwegian University of Science and Technology.

Gary Cokins is an internationally recognized expert, speaker, and author in enterprise and corporate performance management improvement methods and business analytics. He is the founder of Analytics-Based Performance Management, an advisory firm located in Cary, North Carolina at www.garycokins.com . Gary received a BS degree with honors in Industrial Engineering/Operations Research from Cornell University in 1971. He received his MBA with honors from Northwestern University's Kellogg School of Management in 1974.
Gary began his career as a strategic planner with FMC's Link-Belt Division and then served as Financial Controller and Operations Manager. In 1981 Gary began his management consulting career first with Deloitte consulting, and then in 1988 with KPMG consulting. In 1992 Gary headed the National Cost Management Consulting Services for Electronic Data Systems (EDS) now part of HP. From 1997 until 2013 Gary was a Principal Consultant with SAS, a leading provider of business analytics software.
His two most recent books are Performance Management: Integrating Strategy Execution, Methodologies, Risk, and Analytics, and Predictive Business Analytics. His books are published by John Wiley & Sons.