2008

Structural limits of capacity and implications for visibility

Ted Watts
University of Wollongong, tedw@uow.edu.au

Carol J. McNair
US Coast Guard Academy, cmcnair@uow.edu.au

Vicki Baard
University of Wollongong, uow@baard.edu.au

Lidija Polutnik
Babson College

Publication Details

This paper was originally published as Watts, T., McNair, C. J., Baard, V. & Polutnik, L. (2009). Structural limits of capacity and implications for visibility. Journal of Accounting & Organizational Change, 5 (2), 294-312.

Structural limits of capacity and implications for visibility

Abstract

Purpose - This paper fills the gap between defining and measuring the productive *limits* of a machine or system, and the impact of various assumptions about the productive potential of the nature and informativeness of capacity cost management systems. The authors focused on the various ways in which multi-dimensional limits (for example, time, space, volume and/or value-creating ability) can be used to define productive capacity. Specifically, our research suggests that the limits used in establishing the capacity cost management system restrict the amount and nature of the information the system is capable of providing to management.

Justification – Two reasons are identified for studying the impact of capacity measurements on organizations. First, firms which make the best use of their resources can be expected to outperform their competitors. The second arises from the potential structuration effect of capacity metrics. Such an investigation makes capacity a visible, and hence an actionable, construct.

Design/Methodology – To explore these issues, a combination of analytics and qualitative field research methodology was used. The measurement dimensions were developed by analyzing the different reports, baseline measures, and metrics included in the various capacity models as suggested by the literature. These analytics were enriched with observations obtained from field research.

Findings – Maximizing the value created within an organization starts with understanding the nature and capability of all the company's resources. The outcome is the identification of capacity systems specifically suited for particular types of operations, both manufacturing and service.

Practical implications - Such frameworks would allow organisations in developing economies, to make visible, the drivers of waste and productivity and to identify the primary assumptions and implications of various capacity limits.

Keywords

Capacity management, Cost management models, Capacity limits.

Disciplines

Business | Social and Behavioral Sciences

Publication Details

This paper was originally published as Watts, T., McNair, C. J., Baard, V. & Polutnik, L. (2009). Structural limits of capacity and implications for visibility. Journal of Accounting & Organizational Change, 5 (2), 294-312.

Structural Limits of Capacity and Implications for Visibility

Ted Watts*, C.J. McNair,** Vicki Baard,*** and Lidija Polutnik****

University of Wollongong*, US Coast Guard Academy**, Macquarie University*** and Babson College****

Corresponding author
Dr Ted Watts
School of Accounting & Finance
University of Wollongong
Wollongong NSW 2522
Australia

Telephone: 61 2 4221 4005
Fax: 61 2 4221 4297
Email: tedw@uow.edu.au

Acknowledgements

The authors would like to thank the participants of the 2008 *Critical Perspectives on Accounting* Conference and of the *2008 Global Accounting and Organizational Change Conference* for their valuable comments and contributions to earlier versions of this paper. We thank two anonymous referees for their valuable comments. All errors remain ours.

Structural Limits of Capacity and Implications for Visibility

Abstract

Purpose - This paper fills the gap between defining and measuring the productive ***limits*** of a machine or system, and the impact of various assumptions about the productive potential of the nature and informativeness of capacity cost management systems. The authors focused on the various ways in which multi-dimensional limits (for example, time, space, volume and/or value-creating ability) can be used to define productive capacity. Specifically, our research suggests that the limits used in establishing the capacity cost management system restrict the amount and nature of the information the system is capable of providing to management.

Justification – Two reasons are identified for studying the impact of capacity measurements on organizations. First, firms which make the best use of their resources can be expected to outperform their competitors. The second arises from the potential structuration effect of capacity metrics. Such an investigation makes capacity a *visible,* and hence an actionable, construct.

Design/Methodology – To explore these issues, a combination of analytics and qualitative field research methodology was used. The measurement dimensions were developed by analyzing the different reports, baseline measures, and metrics included in the various capacity models as suggested by the literature. These analytics were enriched with observations obtained from field research.

Findings – Maximizing the value created within an organization starts with understanding the nature and capability of all the company's resources. The outcome is the identification of capacity systems specifically suited for particular types of operations, both manufacturing and service.

Practical implications - Such frameworks would allow organisations in developing economies, to make visible, the drivers of waste and productivity and to identify the primary assumptions and implications of various capacity limits.

Key Words - Capacity management, Cost management models, Capacity limits.

Paper type – Research paper.

Structural Limits of Capacity and Implications for Visibility

1. Introduction

There are two quite different, yet compelling, reasons for studying the impact of capacity measurements on organizations. In a purely economic sense, that firms which *ceteris paribus* make best use of their resources can be expected to outperform its competitors (Alchian and Demsetz, 1972). Since capacity measurements help identify the relative degree of productive versus nonproductive utilization this knowledge should be of great value to practitioners and academics interested in economic optimization.

A second and perhaps more compelling reason for being interested in capacity measurement arises from the potential structural effects of capacity measurement metrics. Capacity metrics create a unique "coding" of the time-space dimensions of an organization's productive capability. They create an "analytical and useful space" for calculating, evaluating and comparing performance across multiple machines, systems, or activities (DeBruine and Sopariwala, 1994; McNair and Vangermeersch, 1998), making capacity a *visible,* and hence actionable, construct (Burchell, et al., 1980).

Capacity can be viewed as a measurement of the value-creating ability of a machine or system (McNair and Vangermeersch, 1998). But, how much of this potential resides in any one machine, any one system? It is this issue—the difficulty in defining and measuring the productive ***limits*** of a machine or system—that remains at the heart of debate about capacity analysis and management.[1] When measuring the limit of capacity Debruine and Sopariwala, 1994, used a practical capacity measure based on the capacity the firm expected to activate, however in a later paper Sopariwala (1998) recommends using "maximum available capacity" (p. 34). There is considerable agreement in the existing management accounting literature that it is important to consider theoretical or practical capacity when making strategic and operating decisions (e.g., Cooper and Kaplan 1992; McNair and Vangermeersch 1998). Yet, less attention has been paid to the impact of various assumptions about this productive potential on the nature and informativeness of capacity cost management systems (DeBruine and Sopariwala, 1994; Brierley, et al., 2001). Without this examination it is unclear what exactly are the implications of various definitions of an asset's productive limits (e.g., its base capacity measure), and the choice of one method over another remains one of opinion and preference rather than analytically grounded.

This paper seeks to fill this gap, focusing on the various ways in which multi-dimensional limits (e.g., time, space, volume and/or value-creating ability) can be used to define and make productive capacity more visible. Specifically, this

[1] Many of the early debates and articles on capacity spent considerable time debating how best to define a capacity baseline. Authors such as Gantt (1915a) questioned the specific definition of "normal" capacity, while the NACA debates sought to determine whether practical or normal capacity should be used. One of Gantt's major beliefs was that a firm should use theoretical capacity if it were to truly capture its productive capability as well as its level of waste.

research suggests that the limits used in establishing the capacity cost management system (CCMS) bound the amount and nature of the information the system is capable of providing to management. This paper builds further on existing literature (Hertenstein, et al., 2006) adding additional field study context and data to develop an analytical framework for defining and measuring productive capacity in both manufacturing and service settings. Using the informativeness of the resulting systems, as defined by their completeness, stability and ability to make visible the drivers of waste and productivity (Hopwood, 1983), the analysis will seek to identify the primary assumptions and implications of various capacity limits for visibility and managerial action.

Following the review of existing literature, three different models of capacity measurement and analysis will be explored, beginning with a standard cost models through an approach that links capacity measurement to the market's perception of a firm's value-creating ability. In each case, the role played by the assumed limits of a system's productive capacity on the nature and amount of information the system provides will be examined. These observations and results will then be used to develop a series of conclusions that may serve as the basis for a more complex theory of capacity measurement. Finally, conclusions will be presented with suggestions for future research into the role of limits in capacity cost management.

2. Capacity: An Interdisciplinary Perspective

Historically, capacity analysis has been focused on planning and assessing the utilization of various machines and machine-paced processes within an organization. Capacity utilization measures serve as a leading indicator at a macro-economic level, signaling the health of the economy. When capacity utilization numbers drop, recession becomes a concern. When they reach all-time highs, inflation worries are raised. Given that these metrics play a key role in setting macroeconomic policy, one would assume that they must be fairly well defined and understood. But are they?

Table 1

To begin this discussion of capacity and the concept of limits, it's useful to first develop the basic terminology for the various baseline measures of potential capacity (see Table 1). As can be seen, there are significant differences in the concept of "productive potential" embedded in these various definitions. A firm that believes it can only make 9,000 units with one machine may buy a new asset when it consistently requires more output than this amount, even though it is producing far below the theoretical limits of the machine. In other words, the analytical space created by a normal or budgeted capacity definition appears to mask, or make invisible, this additional productive capability (McNair, et al., 2003).

While it may seem counterintuitive, to suggest that managers will manage from the abstraction or coding of the physical embedded in the capacity measures, there is unfortunately empirical evidence that such blinding to physical reality does occur. As shown by McNair, et al., 2003, managers tend to make asset decisions based not on the theoretical capacity of their assets, but rather on the relationship between normal and future expected demand (see Table 2). Specifically, a manager who believes that future demand is going to require 108.7% utilization of their assets behave differently (e.g., may consider purchasing new assets) than those who perceive their utilization level to be 25.8%. The way in which capacity was defined and presented within the firm's reporting system appeared to alter the surface and deep structures, or conceptualization, of management's decision-making (McNair, 1994: Brausch and Taylor, 1997).

Table 2

Empirical research suggests that annual budgeted capacity is the dominant form of capacity baseline used in European and North American firms (Drury and Tayles, 1994; Brierley, et al., 2001). As noted by Brierley, et al., (2001: 228):

> *There has been a lack of research examining the measurement of the denominator capacity level for overhead rates. From the evidence available, the majority of firms use a measure of budgeted capacity and this is likely to have an adverse impact on the accuracy of product costs.*

Putting this discussion into perspective, average asset utilizations were reported as part of a firm's financial statements prior to 1932 in the United States. Theoretical capacity was the accepted baseline measure during this period. In 1932, in the depths of the Great Depression, U.S. Steel reported it was only at 13% effective utilization of its plant (McNair and Vangermeersch, 1998). It would appear based on the results of current research that many firms may have excess assets at near historical levels, and that these excess assets stand to drive up their cost of production and reduce their competitiveness and profitability in both the short- and long-term.

One final example may be useful at this point. Approximately six years ago, Anheuser-Busch, a leading US brewing company, adopted theoretical capacity denominator activity level as the basis for their capacity cost management system and capacity planning.[2] A primary competitor, Coors Brewing, another US brewer, continued to use budgeted capacity as its denominator activity level. In 2002, a comparison of the asset acquisition policies and overall asset utilizations yielded a striking result. Specifically, Anheuser-Busch experienced increase in both share and total volume, yet noted in their published financial statements that

[2] This information was provided by an anonymous source at Anheuser-Busch who had attended a capacity presentation by Dr. McNair and subsequently notified her that this change had been made.

it had reduced its asset base significantly. In the same period, Coors lost volume yet purchased a significant level of new assets.

Anheuser-Busch continues to obtain share through aggressive price cutting, while increasing its profitability overall. The stock market is rewarding this performance. Conversely, Coors continues to lose share while profits plummet due to reduced industry prices. It would appear from this casual evidence that Alchian and Demsetz's (1972) initial observations are quite applicable to the arena of capacity measurement. Specifically, Anheuser-Busch's superior performance in the beer industry appears to be at least tangentially related to the fact that it appears to know more accurately the relative productive performance of its productive resources. This leads to the first research proposition for this study:

> **Proposition:**
> *The way in which capacity is measured and reported seems to affect management decision-making as well as the economic performance of the firm.*

3. Literature Review

It could be argued that there is a potentially infinite variety of capacity reporting models available to managers in organizations. Yet, March and Shapira (1982) suggest that there may be a relative degree of uniformity in such systems when they note that o*rganizations characteristically do not solve problems; they copy solutions from others* (1982: 98). In other words, it would argue that *ceteris paribus*, a firm is likely to choose among the most publicly available forms of CCMS rather than investing in creating a new system. This being said, three advanced forms of CCMS were identified for use in this study from an examination of the extant literature in capacity (DeBruine and Sopariwala, 1994; Klammer, 1996; McNair and Vangermeersh, 1998):

- CAM-I model
- Logistics model
- Value creation model

Based on the criteria suggested by Feltham (1972) and March and Shapira (1982), these three systems were then compared in terms of their informativeness. Informativeness was defined as the number of dimensions of potential capability they emphasize (e.g., the number of limits established by the system) and the degree to which these dimensions are tightly bounded or defined with respect to their productive potential. Specifically, they were examined in terms of their relative bias (what is made visible), the stability of the resulting cost estimate/signal (the quality of its linkage between past and future results, or uncertainty), and their completeness (the number and type of variances, or underlying variability, they can generate). Table 3 details the way that each of these dimensions was defined and measured.

Table 3

In the 1990s CAM-I (Consortium for Advanced Manufacturing, International), a leading think tank for new management accounting models, embarked on the development of a more robust and informative capacity reporting model that would utilize the power of relational database designs and sophisticated data collection capabilities of modern manufacturing equipment (Klammer, 1996). When describing the CAM-I capacity model, Klammer defined its objective in the following way, "Communicating idle capacity information is one priority of the capacity model" (Klammer 1996, 28).

Debruine and Sopariwala, 1994 argue that using annual budget capacity companies hide excess capacity and are therefore unable to act on it. By employing theoretical or practical capacity measures excess capacity costs can be reported separately and fixed costs become visible (Ostrenga, 1988). Klammer's CAM-I model not only highlights idle capacity, it provides information on the types and reasons for this idle capacity. This information in turn helps management understand the extent to which these non-value-added costs reduce corporate profit and focuses management attention on the need to more fully utilize capacity.

The CAM-I model accounted for all the time available within a capacity system, separating this analysis on two dimensions (1) manned versus unmanned time; and (2) the effectiveness of the utilization of manned time (productive versus non-productive). The costs of the system were also broken into two separate categories: committed and managed. Unmanned hours would be charged committed costs only (e.g., unavoidable fixed asset expenses), while manned time would be charged its share of managed (e.g., resources used to make the machine capable of producing, such as people and power) and committed costs.

Each category of time (idle, productive, and non-productive) is then further broken down by primary cause into a system of variances, including machine breakdowns, planned maintenance, material problems, staffing problems, developmental time, and so forth. Informed by the continuous improvement paradigm, the CAM-I model went beyond traditional definitions to inquire into the underlying categories, or causes of, wasted capacity.

The logistics capacity model takes into account for the fact that in many industries capacity doesn't remain fixed in space and that productive capacity in complex organization may have not one but a variety of productive, value creative uses. For example, assets in a transport firm will be mobile and these assets will exhibit variability in their load factor, or output volume. In order to track output and productivity of assets these types of firms developed "seat miles flown" or "revenue miles flown." These measures focus on the output of the process and not on the process/system capability. They are also relatively unstable over time as changes in prices, volumes, and available seats lead to changes in the capacity metric. Finally, they are incomplete because they do not define any limits or boundary conditions. While they can report variances over time in terms of asset utilization, and can be modified to integrate operational and financial metrics, the failure to set limits creates an ambiguous, and poorly defined, system of capacity measurement.

The traditional CAM-I model needs to be amended to address specificity and complexity of these very different organizations. For example, the number and type of productive, nonproductive and idle time categories needs to be expanded as does the number and type of cost pools in order to reflect the differences in resource demands across various states of capacity utilization.

Our last model of capacity applied and tested in the field is the value creation capacity model. Since capacity is defined as the value-creating ability of an organization's resources and systems, its definition and measurement of value may be relevant for the development of capacity models in a variety of settings.

Capacity modelling in service settings represent a unique challenge because of the inherent intra- and inter-variability in the "capacity" of their core assets—people. Incapable of being bounded, the capacity of service-based systems remains ambiguous and difficult to objectively define and measure.

The cost containment model takes one form of external data, benchmarks, to set standards and performance expectations. These standards are more robust than those that a budget-based, or traditional system, would provide because they do not build from prior internal practices but rather from information about *the potential of the firm's resources to do work*. While tight boundary limits cannot be set on this productive capability, the system does make visible a higher plateau, or potential utilization, that can create the same pattern of decision making and performance improvements of a more complete, stable and unbiased CCMS.

Over the past fifteen years, though, there has been a marked shift in the definition of what "value creation" means in modern organizations (Wayland and Cole, 1994; McNair, et al., 2000; McNair, et al., 2001). Specifically, value creation has been transformed from an internally-defined construct of "value add" and "non-value add" activities as seen in the eyes of management, to an externally-driven metric that builds from the customer's perceptions of the value embedded in a product or service. Customer preferences, or their value profiles, are compared to the value proposition, or attributes of the product or service, to determine the relative competitiveness of one product versus another.

The value creation approach originated in the strategy and marketing literature, and has been primarily focused on defining value segments within the general population and on ways to leverage the firm's core competencies to improve its value proposition. Recent work by McNair, et al., (2000, 2001) has extended these models and systematically connected them with the cost structure of the firm. The results of this research have yielded the development of a five-dimensional definition of cost within an organization: (1) Customer value-add; (2) Business value-add, current; (3) Business value-add, future; (4) Business value-add, administrative; and (5) Non-value add, or waste.

The relative informativeness of the two models is not as easy to evaluate. While it is clear that they make very different aspects of the organization visible, and that the value creation model is a more complete system in terms of the number and type of information signals it provides, it is not possible to do a direct comparison of their informativeness. This comparison would require that one organization invest in developing and using both systems. The information in the two systems is not redundant, but rather complementary. As such, they fail to qualify for comparison under Feltham's (1972) criterion.

This being said, there are other issues raised by the value creation model that affect its informativeness. First, there are nonlinearities inherent in the value creation approach (McNair, et al., 2001). Specifically, one dollar spent on value-add activities will generate more than one dollar of revenue. In fact, these "multipliers" have exceeded a 40:1 ratio for a specific value attribute in some of the studied firms. Dollars spent on anything but value-add fail to generate current revenues at all—they are costs but not revenue-generating. This is a new concept in costing, one that may be initially difficult for managers to understand. Feltham (1972) would suggest that the value of this information may be reduced because of this uncertainty. Over time, this ambiguity should be reduced, but there is little or no expectation that the measures developed by the value creation approach will stabilize.

In many respects, then, the value creation-based capacity system may be inferior in terms of the criteria of informativeness developed here. But, it is equally possible that it may serve to change decisions in organizations to a much greater degree than traditional capacity models because it makes visible a new dimension of capacity—its ability to generate revenue growth. It is a strategic model, rather than an operational or tactical model of capacity. As such, it may ultimately have a greater impact on an organization because it has changed the calculative space of the firm. These potential impacts remain untested and unknown due to the recent nature of this project and the underlying literature and research that it builds upon.

4. Research Methodology and Description

A combination of analytics and qualitative, field research methodology (Yin, 1984; Strauss and Corbin, 1998; Glaser and Strauss, 1967) was used to test the propositions underlying this study. Specifically, the measurement dimensions were developed separately by at least three experts who analyzed the different reports, baseline measures suggested, and metrics included in the various capacity models as suggested by the existing literature on the models.[3] These analytics were enriched with observations obtained from field research conducted in three sites covering the period spanning 1998-2003.

Table 4

[3] In each case, the two researchers evaluated the systems on the stated dimensions. In addition, three outside experts on capacity analysis, Dr. Richard Vangermeersch of the University of Rhode Island, Dr. Holly Johnston of Babson College, and Dr. Riccardo Silvi of the University of Bologna provided assessments of one or more of the models on the defined measurements.

The details of each site, the study time period and number of site visits, and the capacity cost model used by the firm are presented in Table 4. As the table details, the site work was conducted over a period of five years. The firms in the study were drawn from both the manufacturing and service sectors. The size of the organizations studied varied greatly, ranging from Specialty Foods, a medium sized service firm providing "ready-to-eat" food items within a commercial grocery store setting to a large commercial airline that posted $3.2 billion in sales and a workforce of 22,000.

The data collection activities focused on the comments and observed actions of managers at the sites, as well as the actual capacity reports and metrics used within the organization. The on-site data collection was conducted as part of a longitudinal interpretative, grounded theory initiative (Glaser and Strauss, 1967). The interpretative paradigm recognizes that the researcher is actively involved in creating the reality, and interpreting the results obtained, during research within an organization. To alleviate some of the empirical concerns embedded in grounded research, subject statements are provided to the reader to provide a basis for assessment of the research findings or development of alternative interpretations.

Having explored the basic theory, methods, and measurements used, attention now turns to the analysis of the three competing models and historical/empirical evidence of their informativeness.

5. Informativeness in Action: Analytical and Empirical Results

A capacity reporting system is a particular type of accounting system, one that emphasizes the productivity of an asset or system against some preset expectation, or standard, of its perceived potential to create value for the organization and its primary stakeholders (McNair and Vangermeersch, 1998). By the events they record, and those they ignore, these systems can be argued to create a form of reality for the organization—to shape its calculative and physical space.

A CCMS, though, is also a reflection of the organizations in which it is used (Hopwood, 1983). Metrics and reports that are deemed to be of little or no value to decision makers are unlikely to be incorporated in these systems (Feltham, 1972), regardless of their potential informativeness. These findings by prior researchers suggest that a one dimensional analysis and inquiry into the value and nature of capacity reporting will by nature be incomplete and inconclusive. Reflecting these arguments, our research findings will integrate analytical, archival, and empirical data based on three different field studies which incorporate and build upon the three capacity reporting systems presented earlier.

5.1 Expanding the Limits: The CAM-I Model

In 1998, Windows, Inc. determined that it needed to improve its operational measures and improve the integration of its financial measures (standard costing) with the measures used to manage the plant floor. Ongoing decision support problems were noted to be the driver of this change, as described by the financial manager of the business development group:

> *We are having major problems with the launch of our new product line…and it sure doesn't help that it takes so long to calculate costs. The guys are changing the design every other day, taking out features and changing methods. But, they're flying blind….frankly, we aren't of much help. We aren't even into production and everyone is already ignoring the information out of the costing system…The plant floor has implemented TQM, lean production, and many other innovations that cut the time and cost to make a window. But, we haven't changed the costing system. Translation? There's no way to prove that these changes have or have not improved the bottom line. We don't really know what the plant is capable of, whether it is improving, or how to assess the impact of new demand on our resources, or any other of a number of important things.. As a result, I'm sure we're making questionable decisions….but unless we get some new tools, we're not going to be able to convince anyone—even ourselves!!!.*

The production of windows is both capital- and labor-intensive. The window assembly lines have high labor content, but remain paced by one or two key machines that perform difficult or dangerous operations. Windows also manufactures a wide range of basic wood components for its windows and maintains the capability to extrude plastic coverings on its core wood components to improve the appearance, durability, and ease of use of its products.

The inadequacies of the standard costing model within a more traditional manufacturing setting were highlighted above. These problems expand as the demand for decision support information grows, and as the emphasis on identifying and eliminating waste from production increases. In other words, the bias inherent in standard costing had made it irrelevant.

When the CAM-I model was implemented, there was an immediate reaction from managers throughout the organization—some positive, some not so, as the following comments by the V.P. of Operations suggest:

> *I knew, somehow, that things just weren't going as planned in the door subgroup. But I couldn't put my finger on what it was…I mean, the numbers in our reports were all in line, yet I couldn't see how all of those expensive machines were in the end buying us very much. Volumes hadn't changed, so it only made sense that the cost of a door must have gone up, but every time I looked at the accounting reports, it just wasn't there. So…I figured I was missing something. Guess now I'd have to say I wasn't.*
>
> *I like this; by the way….I can finally compare these cost centers in some meaningful way. The apples-to-apples stuff…that helps me counter a cost center manager's claim that his or her group can't be compared to another…I can finally hold them all to the same set of criteria, and track whether they're getting better. But, I don't know how they'll feel about it…that will be an interesting discussion.*

The CAM-I model provided a level of comparability for a diverse set of operations in the plant that had not been available before, a key aspect of informativeness (Alchian and Demsetz, 1972). It also provided a means for tracking historical utilizations and to assess the effectiveness of new asset purchases in terms of actual cost and efficiency effects. The door sub-plant, which was a “star” prior to the capacity analysis, was now found to have failed to gain the labor and cost improvements it had promised would result from the acquisition of new equipment. On the other hand, the extrusion plant, which had been noted to be a major problem, was found to have high levels of utilization and marked improvements in overall costs and performance over the study period.

Assessing the CAM-I capacity model against the dimensions of informativeness developed by Feltham (1972), it appears to be less biased than standard costing or the operational perspective because it makes visible a wider range of productive dimensions that correspond to primary causes of waste and cost in manufacturing. Its operational capacity measures are stable over time, due to the use of theoretical time and rates. In addition, productive capacity is calculated using a stable measure of the consumption of capacity by one unit of output—*cycle time,* or the amount of elapsed time between units coming off the production line. Cycle time is constant for each type of product, and can easily accommodate a variety of units with different time demands on the bottleneck.

On the cost side, its metrics have been broken into two primary categories corresponding to how responsive the cost is to changes in utilization. This suggests that the cost metric is also more stable than that developed under standard costing. In terms of completeness, the number of limits has been expanded significantly to two on the operational side, and one on the cost side. The capacity information has been broken into a wide number of variances that reflect the primary causes for idle and non-productive time and cost. Finally, it is inclusive in that the cost and operational information have been integrated into one report that makes comparison of these two primary performance dimensions visible. It would seem that the CAM-I model is significantly more informative than the standard cost and operational capacity models.

5.2 Boundaries in Space and Time: Logistics and Capacity

Focused on providing low cost air transportation, Easy Air had always managed its fleet of planes with one driving goal: to maximize the time in the air. The reason for this was simple—only when a passenger was en route was the firm earning revenue. Easy Air utilized “seat miles flown” and “revenue miles earned” to track their productivity. This logic, reinforced by the industry-defined measure of capacity and the beliefs of its founder, had fueled profitable growth at Easy Air in an industry notorious for massive losses and business failures.

In the late 1990s as the industry and the company experienced volatility in prices, changes in volumes and available seats these traditional logistics capacity measures didn’t provide best information in terms of costing the capacity system.

A senior financial manager at Easy Air succinctly described the problems his company was facing, and the goals it was pursuing:

> *We sure don't want to end up like the rest of our competitors, losing money by the bucket and not knowing how to make things better. No matter how good things get….we simply have to manage the company in good times so we can survive the bad times. And there have been some awfully bad times lately for the airline industry. We just don't use them as an excuse…they are a challenge, a reason to keep looking for ways to get a little bit better at what we do.*
>
> *That's why we're so hooked into this capacity issue…heck, we fly our assets all over the place and we only make money when people are on them and we're getting them where they want to go on time with no hiccups along the way. But right now we're measuring it just like everyone else. It doesn't feel right, but to date we just haven't found a better way. I worry, though…if we're using the same measures, won't we risk getting the same results? How do we know if we're getting better or simply growing volume? Where could we improve and what would it mean? These are the questions I get asked to look at…and I don't have a good answer right now….*

The Easy Air site provided an excellent opportunity to look at the informativeness of a capacity reporting system that was unbounded with one that was more completely defined. The challenge was to identify the number and type of limits necessary to stabilize the cost and capacity metrics the system would develop.

In examining capacity from the perspective of its boundaries or maximum ability to create value, it became clear to the project team that capacity for an airline would need to be bound in time, in "space" (e.g., load factor), and the degree of effective utilization of this "time and space" form of capacity. Three specific limits were required to frame the capacity of the system. None of these limits, though, emphasized the distance flown, which had been the prior definition of capacity. Distance was not a dimension of value creation that was easily bounded—many factors influenced how many miles were flown on any one day by any one plane, creating ambiguity in the resulting metric. Time and available seats per plane (or "tail" in airline terms), on the other hand, could be tightly defined. No matter what was done with a plane, it was only available for 8,760 hours a year and could only convey a specific number of passengers at any time.

As the extensive research project on measuring capacity at Easy Air evolved, it became clear that there was one other boundary or condition that would need to be considered to effectively capture not only the potential capacity of an airplane but also how and why variations in utilization occurred. While there were air control and weather issues affecting the plane while en route, the major issues it struggled with emerged when the plane was on the ground—the interaction of the plane with ground operations placed unique limits on the plane's productive capacity. To the extent that ground operations, such as loading and unloading baggage and boarding passengers, was done inefficiently, plane-based capacity would be sacrificed.

Figure 1

The capacity model that was derived from this analysis is presented in Figure 1. As can be seen, the number and type of productive, nonproductive and idle time categories have expanded significantly, reflecting the addition of additional limits to the CAM-I model. Similarly, the number and type of cost pools was greatly expanded to reflect the differences in resource demands across various states of capacity utilization. This expansion in cost pools included the development of ground operation costs (capacity and activity-based) for those times when the plane was at a gate or being serviced. Failures, such as problems with bag handling, lost luggage, or stranded passengers, were also analyzed for their impact on plane capacity and the total costs incurred by Easy Air during its normal operations.

The new capacity system reflected a marked improvement in the informativeness. Specifically, it made a greater number of forms of utilization visible, and focused on a clearly defined and bounded aspect of capacity, making it less biased than the prior model used by the firm. Having established these limits tightly, the resulting measurements became quite stable over time and volume changes—these changes were explained, not hidden in a moving average or measure of capacity. The system was also much more complete on every dimension of this construct—number of limits, number of variances supported, and inclusiveness/number of cost pools.

Easy Air's transition from one system of capacity reporting to a second provides the clearest illustration of Feltham's (1972) arguments. Since it can be assumed that the other information signals received by management were unchanged by the change in capacity reports, the information value embedded in these two systems can be compared and evaluated. The issue that remains, though, is whether this change in information content leads to changes in decisions and behavior—does what the CCMS makes visible influence decision makers?

Figure 2

Several events subsequent to the roll-out of the revised CCMS suggest that changes are beginning to occur. The most marked of these changes is illustrated in Figure 2. When the total capacity of the company was summarized across a normal operating day, the radical ramp up in flights and plane utilization that began at 9 am East coast time (EST) and ended at 7 pm on the West cost (PT) became quite obvious. What was clear in talking with Easy Air managers was that they had not been aware of this phenomenon—it was not visible or apparent in their traditional capacity system because this system did not track utilization in terms of time.

Once the issue of shoulder time was understood, management turned its attention to identifying the incremental profit of adding flights to the beginning and end of the day—to increasing its level of productive capacity utilization. The change in the CCMS had had the required effect to qualify as a change in its information value—it had changed management's understanding of the problem as well as the decisions being made within the firm.

5.3 Revisiting Capacity in Service Settings: The Role of Customer Value Creation

Specialty Foods is a large specialty food producer whose employees perform a variety of activities.[4] Specialty Foods provides one illustration of how capacity cost systems may evolve (see Figure 3) to incorporate value creating capability of the systems. Variances are developed for each of the five primary states of capacity. The model, reflecting the basic report structure developed by CAM-I (Klammer, 1996), emphasizes total value created across the range of activities performed by Specialty Foods' employees. As suggested earlier these activities need to be sorted in non-value add, business value-add-administrative, business value-add-future and current and customer value add. While the capacity reporting grid has not been fully populated for this example, the firm is currently collecting the information required to complete it. Data collection process is resulting in some interesting conversations at Specialty Foods as employees think of connections between time spent and the ability of activities performed to impact revenue generation.

Figure 3

How does the informativeness of this system compare to that of the traditional cost containment model? Both incorporate externally-defined limits to offset some of the inherent measurement problems in service settings. Both are relatively unbounded, in that the maximum amount of value the organization could create cannot be defined. Both incorporate both operational and financial metrics and present a reasonable number of variances to explain variability in performance.

The primary difference between the two models lies in their definition of capacity. The cost containment model attempts to use a more traditional measure of capacity utilization—the productivity of the firm's assets. It is a cost-centered and cost improvement-driven approach. The value creation approach, on the other hand, emphasizes the revenue generating capabilities of the firm's resources. Productive time becomes tightly defined as the time and costs incurred that a customer directly benefits from. In this respect, the value creation model more

[4] As with all of the reports and analysis presented in this paper, the actual numbers, results, and features of Specialty Foods has been disguised. The transformations used retained the accuracy of the underlying relationships, but were scaled to hide the true identify of the firm.

closely proxies the concept of cycle time and productive cost in more well defined machine-paced settings.

6. Summary and Opportunities for Future Research

The purpose of this paper was to fill the gap between defining and measuring the productive ***limits*** of a machine or system, and the impact of various assumptions about the productive potential and the nature and informativeness of the CCMS. This was done by testing the proposition that the way in which capacity is measured and reported seems to affect the management decision-making as well as the economic performance of the firm. To confirm this, three advanced CCMS models were tested in different organizational settings. These three systems, their basic description, and the nature of the limits they place on resource capacity are summarized in Table 5.

Table 5

Specifically, this research suggests that the limits used in establishing the capacity cost management system restricts the amount and nature of the information the system is capable of providing to management. Maximizing the value created within an organization starts with understanding the nature and capability of all the company's resources. The outcome is the identification of capacity systems specifically suited for particular types of operations, both manufacturing and service. Such frameworks would allow organisations in developing economies, to make visible, the drivers of waste and productivity and to identify the primary assumptions and implications of various capacity limits. In particular when assessing the CAM-I capacity model against the dimensions of informativeness developed by Feltham (1972), it appears to be less biased than standard costing or the operational perspective because it makes visible a wider range of productive dimensions that correspond to primary causes of waste and cost in manufacturing.

With the logistics model, the CCMS had the required effect of qualifying as a change in its information value—it had changed management's understanding of the problem, as well as the decisions being made within the firm. With respect to the value creation model it may be inferior in terms of the criteria of informativeness developed here. But, it is equally possible that it may serve to change decisions in organizations to a much greater degree than traditional capacity models, because it makes visible a new dimension of capacity—its ability to generate revenue growth. It is a strategic model, rather than an operational or tactical model of capacity.

Opportunities for future work in the area of CCMS exist in further exploration of visibility of limits on the capacity measures and systems. There is a need for more data from different organizational contexts and decisions for which capacity systems are needed. While the data from three field study suggests the benefits of better visibility of CCMS for decision-making, more work is needed to better understand how managers interpreted the information from different capacity systems and what alternative courses of action might be considered with alternative capacity cost information and knowledge. More work needs to be done to identify the modeling of connecting capacity cost systems) to incorporate value creating capability of the systems. This paper contributes to the existing literature on capacity cost and visibility (Brierley et al., 2001). Overall the authors believe that these models and their adoption to specific organizational types, will allow firms which make the best use of their resources, to outperform their competitors and enable specific investigations which make capacity a *visible,* and hence an actionable, construct.

Table 1 Basic Capacity Measurements and Definitions

Capacity Measure	Definition	Example
Theoretical	The maximum amount of capability of a machine or process. In practice this is often described as "24-7, The best you can be."	There is a maximum of 8,760 available hours in a year. If a machine can produce, at best, one unit every 10 minutes, its theoretical capacity would be 52,560 units of output.
Practical	Theoretical capacity reduced for "unavoidable" downtime. In practice, engineering estimates normally reduce theoretical by 30% as a first pass at establishing practical capacity limits.	There are still 8,760 hours in a year, but now we only expect to make a unit every 14.3 minutes (10/.7). The practical capacity would be 36,792 units of output (8760 times 60/14.3).
Normal	Normal capacity is the average utilization of an asset over a 3 to 5 year period. Note that attention has been turned away from the capability of the machine or process to the way in which that asset is utilized.	Let's now assume our machine is only run one shift per day. Its normal capacity would be 8,736 units (2080 hrs. times 60/14.3), or only 16.7% of the original capability of the asset.
Budget	The coming years expected demand for output from a machine or process. Once again, the planned utilization, not capability, of the asset serves as the basis for this definition.	The firm expects to produce 9,000 units in the coming year on this machine.
Actual	The actual production achieved with the asset for a given period.	The firm was able to produce 9,500 units during the year.

Table 2 Comparative Capacity Utilization Metrics

Capacity Baseline	Actual Utilization	Utilization Metric (Actual over Baseline)	Name of Metric
Budgeted capacity (9,000 units)	9,500 units	$\frac{9,500}{9,000}$ or 105.6% Utilization	Variance to Budget
Normal capacity (8,736 units)	9,500 units	$\frac{9,500}{8,736}$ or 108.7% Utilization	Variance to Normal
Practical capacity (36,792 units)	9,500 units	$\frac{9,500}{36,792}$ or 25.8% Utilization	Variance to Practical
Theoretical capacity (56,250 units)	9,500 units	$\frac{9,500}{56,250}$ or 18.1% Utilization	Variance to Theoretical

Table 3 Dimensions of Measurements Used

Dimension	Measurements	Definition
Degree of bias	Emphasis	What dimension of system capacity is measured?
	Visibility	The number of productive and nonproductive capacity uses that are identified, tracked and reported by the system.
Stability	Consistency of signal over time	The number/size of the capacity baseline measure from one period to the next.
	Consistency of signal over various levels of utilization	The degree of change in cost estimates as productive volumes change.
Completeness	Scope	Number of limits
	Variability	Number of variances
	Inclusiveness	Number of cost pools and/or estimates incorporated

Table 4 Description of Field Research Site Characteristics

Issue	Windows Inc	Easy Air	Specialty Foods
Period of study	1998-2000	2000-2003	2003
Total site visits	30	18	12
Primary business	Residential windows and doors	Passenger air travel	"Ready-to-eat" specialty foods
Estimated revenues	$1.5 billion	$4.5 billion	$ 10 million
Number of employees	4,500	22,000	200
Type of CCMS used	CAM-I	Logistics	Value-Creation

Figure 1

Capacity Report

Year Ending: 12/31/2000

(in millions of dollars)

Industry Specific	*Category*	*Hours*	*% of total hrs*	*Cost Code*	*Cost Rate*	*Total Dollars*	*% of total $'s*
Off Limits	Airport/Flying Restrictions						
Marketable	Unscheduled--Idle in Hangar						
Total Idle Capacity							
Standby	Repositioning Aircraft						
	Idle--Scheduling Gap						
Service Quality Issues--Delays	Crew Shortages--Scheduling Problems						
	Repositioning aircraft--schedule prob.						
	Baggage handling delays						
	Wait for connecting flights						
Maintenance	Unplanned Maintenance						
	Scheduled Maintenance						
Set-ups	Allowable gate/turn time						
	Excess gate/turn time						
	Airplane servicing						
Load Factor Loss (Yield)	Airborne Time						
	Taxi/Take-Off						
	Landing/Taxi In						
Uncontrollable Delays	Weather delays/rerouting						
	Air traffic delays--in flight						
	Passenger emergencies						
	Airport delays--on ground						
Non-Work Related	Personnel training						
	Developmental projects						
Total Non-Productive							
Airborne Time							
Taxi/Take Off							
Landing/Taxi-in							
Total Productive							
Total Capacity Hours + Costs							

Figure 2 “Shoulder Time” at Easy Air

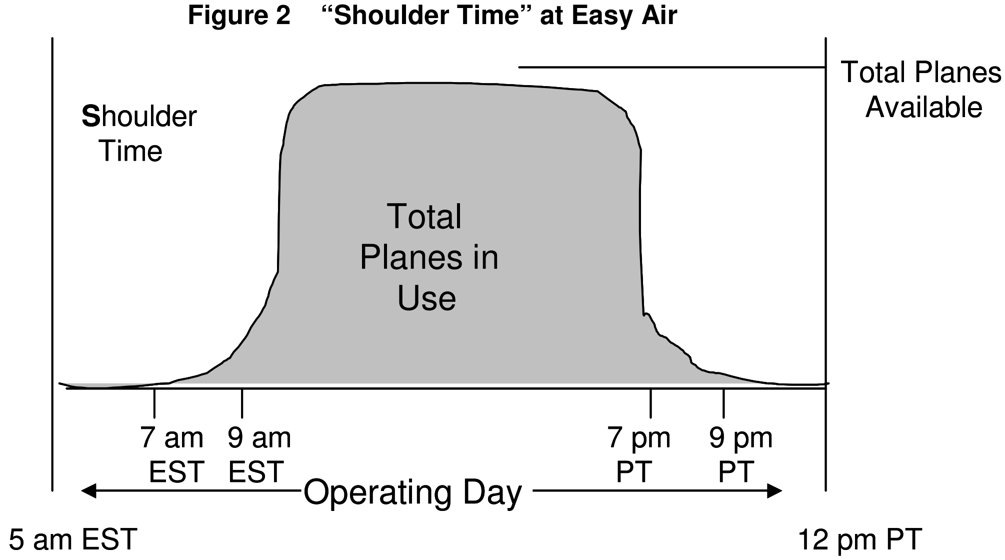

Figure 3 A Sample Value Creation Capacity Report

Capacity Report

Specialty Foods

Summary Category		Category	Hours	% of total hrs	Rate	Total Dollars	% of total $'s	Cost/ Good unit
Idle Capacity	Off Limits	Management Policy (Holidays)	85.00	0.5%	$ 5.25	$ 446	0.15%	$ 0.031
	Marketable	Idle but Usable	2,843.00	16.2%	$ 5.25	$ 14,926	4.94%	$ 1.051
Total Idle Capacity			**2,928.00**	**16.7%**	**$ 5.25**	**$ 15,372**	**5.09%**	**$ 1.083**
Non-Value Add		Paid Breaks		0.0%	$ 19.65	$ -	0.00%	$ -
		Excess time in prep	11,284.50	64.4%	$ 19.65	$ 221,740	73.40%	$ 15.616
		Scrap		0.0%	$ 19.65	$ -	0.00%	$ -
Business Value-Add--Administrative		Meetings		0.0%	$ 19.65	$ -	0.00%	$ -
		Ordering		0.0%	$ 19.65	$ -	0.00%	$ -
		Inventory		0.0%	$ 19.65	$ -	0.00%	$ -
Business Value-Add--Future		Training		0.0%	$ 19.65	$ -	0.00%	$ -
		Create new recipes/Products		0.0%	$ 19.65	$ -	0.00%	$ -
Business Value-Add--Current		Rotate stock		0.0%	$ 19.65	$ -	0.00%	$ -
		Prep batch	290.00	1.7%	$ 19.65	$ 5,699	1.89%	$ 0.401
		Clean-up from batch	377.50	2.2%	$ 19.65	$ 7,418	2.46%	$ 0.522
		Fill cases		0.0%	$ 19.65	$ -	0.00%	$ -
Total Business Value-Add and Non-Value Add			**11,952.00**	**68.2%**	**$ 19.65**	**$ 234,857**	**77.74%**	**$ 16.539**
Customer Value Add		Food Quality	2,640.00	15.1%	$ 19.65	$ 51,876	17.17%	$ 3.653
		Food Healthiness		0.0%	$ 19.65	$ -	0.00%	$ -
		Service Quality		0.0%	$ 19.65	$ -	0.00%	$ -
		Presentation/Cleanliness		0.0%	$ 19.65	$ -	0.00%	$ -
Total Customer Value Add			**2,640.00**	**15.1%**	**$ 19.65**	**$ 51,876**	**17.17%**	**$ 3.653**
Total Capacity Hours + Costs			**17,520.00**	**100.0%**		**$ 302,105**	**100.00%**	**$ 21.275**
	Number of employees	2						

Table 5 A Range of CCMS Models

Capacity Model	Description	Comments
CAM-I Model (Klammer, 1996)	Shifts attention to the "state of preparedness" (Church, 1934) of the underlying asset or system. Classifies capacity utilization in terms of various categories of productive, nonproductive, and idle time.	Theoretical capacity baseline is adopted. Two primary limits established within system: time and effectiveness of utilization. Economic impact of capacity utilization integrated into model through use of committed and managed capacity costs.
Logistics Model (McNair, et al., 2003)	Examines shifts in definition of capacity as the asset is allowed to move within space. Interdependence between assets or systems is examined as the core asset moves within space. Activity costs used to fully capture the economic implications of different forms of variation and interaction between systems.	Theoretical capacity baselines developed on four dimensions: Time, space or volume of the core asset, effectiveness of core asset utilization, and interaction of core asset with other primary systems or assets. Cost model expanded to include multiple states of preparedness, utilization, and interaction with other systems.
Value Creation Approach (McNair, et al., 2000; 2003)	Shifts focus of definition of productive utilization from an internal perspective (defined on units produced or activities performed) to an external perspective (customer-defined value creation). Underlying definitions of utilization and value become increasingly perceptual. Emphasis shifts from one asset or system to the organization's capability to create value.	Limits defined now on both physical features (time, space, effectiveness of core asset utilization and potential interactions) as well as the value-creating ability of the productive effort (value-add, business value-add, and nonvalue-add). Limits and costs established in terms of perceptual features, such as the value creating capability of a resource, activity or system are unbounded, nonlinear, and unstable. Cost model expanded to include multiple dimensions of productive and nonproductive capacity across the organization.

References

Ahmed, M. N and Scapens, R, W. (2000). "Cost Allocation in Britain: Towards an Institutional Analysis", *European Accounting Review*, Vol. 9 N. 2, pp. 159-204.

Alchian, A. A., and Demsetz, H. (1972) "Production, Information Costs, and Economic Organization", *The American Economic Review*, Vol. 62 No. 5, pp. 777-795.

Brausch, J. M. and T. C. Taylor. (1997). "Who is accounting for the cost of capacity?" *Management Accounting* (February) Vol. 44-46, pp. 48-50.

Brierley, J. A., Cowton, C. J. and Drury, C. (2001). "Research into Product Costing Practice: A European Perspective", *European Accounting Review*, Vol.10 No. 2, pp. 215-256.

Burchell, S., Clubb, C., Hopwood, A. and Hughes, J. (1980) "The Role of Accounting in Organizations and Society", *Accounting, Organizations and Society*, Vol. 5 No. 1, pp. 5-27.

Church, A. H. (1915a), "Mr. Gantt's Theory of Expense Burden", *American Machinist*, Vol. 43, July 29, pp. 209-210.

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

DeBruine, M. and Sopariwala, P. R., (1994). "The Use of Practical Capacity", *Cost Management*, Vol. 8 No. 1, pp. 25-31.

Drury, C. and Tayles, M. (1994). "Product Coating in UK Manufacturing Organizations", *European Accounting Review*, Vol. 3, pp. 443-469.

Feltham, G. A. (1972). *Information Evaluation*, Sarasota, FL: American Accounting Association.

Gantt, H. L. (1915a). "The Relation Between Production and Costs", *American Machinist*, Vol. 43, June 17, pp. 1055-1056; 1061-1062.

Glaser, B. G. and Strauss, A. L. (1967). *The Discovery of Grounded Theory: Strategies for Qualitative Research*, Chicago: Aldine Publishing.

Hertenstein, H. J., Polutnik L. and C.J. McNair (2006). "Capacity Cost Measures and Decisions: Two Field Studies", *The Journal of Corporate Accounting and Finance*, pp.63-77.

Hopwood, A, G, (1983). "On Trying to Study Accounting in the Contexts in Which it Operates", *Accounting, Organizations and Society,* Vol. 8 No. 2/3, pp. 287-316.

Klammer, T, P. (1996). *Capacity Measurement & Improvement: A Manager's Guide to Evaluating and Optimizing Capacity.* Irwin, Burr Ridge, Ill.

March J., G. and Shapira, Z. (1982). "Behavioral Decision Theory and Organizational Decision Theory", in Gerardo, R. Braunstein, U. and Braunstein, D, M. *Decision Making: An Interdisciplinary Inquiry,* Boston, Kent, pp. 92-115.

McNair, C. J. (1994). "The Hidden Costs of Capacity". *Journal of Cost Management* (Spring): Vol. 8 No. 1, pp. 12-24.

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

McNair, C.J., Polutnik, L. and Silvi, R. (2000). Outside-In: Cost and the Creation of Customer Value", *Advances in Management Accounting*, M. Epstein, ed., Vol. 9, pp. 1-12.

McNair, C.J., Polutnik, L., Hertenstein, J. and Vangermeersch. R. (2001). "Capacity Cost Management", *Handbook of Cost Management*, Spring.

McNair, C.J., Polutnik, L, Johnston, H, Augustyn, J. and Thomas, C. (2003). "Shifting Perspectives: Accounting, Visibility, and Management Action", *Advances in Management Accounting*, Marc Epstein, ed., Vol. 10, pp. 1-38.

Ostrenga, M, R. (1988) "A Methodology for Identifying your Excess Capacity Costs", *Journal of Cost Management for the Management Industry,* Vol. 2 No. 2, pp. 39-44.

Sopariwala, Parvez R. (1998) "Using Practical Capacity for Determining Fixed Overhead Rates," *Journal of Cost Management*, September 1, pp. 34-40.

Strauss, A. L., and Corbin, J. M. (1998). *Basis of Qualitative Research: Techniques and Procedures for Developing Grounded Theory,* Thousand Oaks, CA: Sage Publications.

Wayland, R. E. and Cole, P. M. (1994). "Turn Customer Service into Customer Profitability", *Management Review,* Vol. 83 No. 7, pp. 22-24

Yin, R. K. (1984). "*Case* Study Research Design and Methods", *Applied Social Research Methods*, Series 5. Thousand Oaks, CA: Sage.

Corresponding Author – Ted Watts can be contacted at tedw@uow.edu.au