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Assessing the Significance of Modularizing Contract Manufacturing Organizations

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Walden University
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Abstract

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Dissertation Submitted in Partial Fulfillment

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Abstract

Organizations are under constant threat from global competition, socioeconomic factors, and political forces that are often unforeseen and dynamic. Consequently, decision makers adopt strategies, some including the principles of modularity, as a countermeasure. The problem addressed in this study was the lack of knowledge about the significance of modularizing contract manufacturing organizations (CMOs). The purpose of this quasi-experimental study was to assess the significance of modularizing CMOs by statistically analyzing capacity utilization, efficiency, and profit margin between modular and nonmodular departments in a focal CMO. This study was grounded in the theory of modularity and the research question addressed what might be the significant value of implementing organizational modularity. The hypotheses posited that a significant difference exists in these metrics between the modular and nonmodular departments of the focal company. ANCOVA was applied to the hypotheses using secondary data of complete job orders undertaken at a company from 2008 to 2013. The results indicated significant differences in capacity utilization, efficiency, and profit margin between modular and nonmodular departments after controlling for differences based on overhead cost or lead-time. Decision makers in manufacturing companies, particularly those in CMOs, may benefit from these findings because they provide answers to questions on the value of modularizing CMOs. The social change implications of this study are based on companies gaining knowledge to improve productivity, manufacture more affordable goods, and provide more skilled employment opportunities. As a result, more people leave poverty and experience an improved quality of life.

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Dedication

I dedicate this work to my wife, Membari; my daughter, Ziirabari; and my sons, Sipbari and Zuabari. Zii and Sip-boy, you endured my absence not only from the dining room table but also from the study room during your homework because I had to study as well; this is also your success.

Acknowledgments

Thank you is not a sufficient expression of the level of gratitude that I wish to express to my dissertation committee members. The successful completion of this program is due in large part to the support and guidance of my mentor and dissertation committee chair—Dr. David Gould, my methodology expert—Dr. Mohammad Sharifzadeh, and my University Research Reviewer—Dr. Christos Makrigeorgis. I will ever remain grateful and appreciative of your tutelage and encouragement.

Table of Contents

List of Tables

List of Figures

Chapter 1: Introduction to the Study

This was a quantitative study that included a quasi-experimental research design in assessing the significance of modularizing contract manufacturing organizations (CMOs). In this chapter, I cover the background of the study, the problem statement, and definition of terms, and I introduce the research questions and variables for statistical analyses of significance. The chapter concludes with a summary and transition statement section.

Background of the Study

Schilling and Steensma (2001) recommended extending the study of modularity to contract manufacturing (CM). In examining the driving factor behind modular form organizations, Schilling and Steensma relied on a model based on flexibility. They argued that although the demand for customization could drive modular organizational forms, other models were necessary for other areas including CM. Liao, Tu, and Marsillac (2010) supported the premise that modularity-based manufacturing provides flexibility and recommended the expansion of studies on modular perspectives by investigating other measurement items to better understand the effect of modularity.

I examined the significance of organizational modularity (OM) within the domain of CM, and the result is crucial because managers rely on it for the action to take in a highly globalized and competitive economy. The wrong decision could potentially cause the XYZ Company, a pseudonym, to fail. By understanding the economic relevance of OM as it relates to CMs, decision makers in organizations may be better equipped to design strategic plans with higher potential for the overall success of the organization. I examined the significance of OM using the XYZ Company as the focal organization.

The Origin of Modularity

The theory of modularity originated from the study and formation of complex systems. Simon (1962) introduced the concept of modularity while exploring complex systems. According to Simon, systems are complex if they consist of large numbers of parts that interact in ways that are not simple. Simon theorized that complex systems consist of subsystems occurring in hierarchical form. The subsystems are the modules from which modularity and the theory of modularity derives. Alexander (1964) referred to the concept of modularity as a piecemeal approach that is capable of forming adaptive systems for humans.

Modularity also refers to substructures capable of singular or multiple interactions with other internal or external structures within a complex system (Bask, Lipponen, Rajahonka, & Tinnilä, 2011; Simon, 1962; Zhang, 2011). The substructure is also a module. The internal components of a substructure may perform several activities; however, they all contribute to the unique function of the module. A level of internal interaction exists between components of the substructure. The number of modules in the system is a function of the system's complexity. Thus, Simon defined a *complex system* as a system consisting of modules, which interact in nonsimple ways and, which together, create a much larger unit. As Simon noted, complex systems occur in natural and social systems in hierarchical forms. For example, the supervisor to subordinate hierarchy exists in business organizations. In nature, cells, tissues, organs, and animals form in a complex progression. This simplistic concept of modularity is common and useful.

Using the parable of two watchmakers, Simon (1962) attempted to explain the benefit in applying the concept of modularity. According to Simon, Hora and Tempus were successful watchmakers at the time, but Tempus lost his business. Hora assembled each watch by first assembling subassemblies or modules so that interruptions would not necessitate starting over. The modular approach allowed Hora to assemble more watches and kept up with demand. Tempus did not use a modular approach. Tempus restarted the assembly for each interruption. Eventually, Tempus could not deliver on time and lost customers. Although the concept of modularity has since succeeded in a variety of fields, a generally acceptable definition of *modularity* has not been achieved.

Defining *Modularity*

Proponents of the theory of modularity exist across various disciplines, and the definitions of *modularity* accordingly vary. Modularity is multidisciplinary and fast becoming a focal area of interest (O’Neil, 2015; Stjepandić, Ostrosi, Fougères, & Kurth, 2015). The definition of *modularity* lacks uniformity because of its popularity and application in various fields (Bask et al., 2011; Campagnolo & Camuffo, 2009; Salvador, 2007; Yang & Tempero, 2007). Each discipline skews the definition of *modularity* to satisfy its focus. For example, in operations management, modularity reflects the divisibility of products into components easily changed (Guo, 2007; Heizer & Rendner, 2004; Pekkarinen & Ulkuniemi, 2008). In software engineering, modularity is the discreteness of components in a computer program and the degree of effect that a change in one component may have on another (Yang & Tempero, 2007). Evidently, adapting the definition of *modularity* to suit a particular discipline is a common and acceptable phenomenon.

Various definitions of *modularity* exist; however, the definition by Baldwin and Clark (1997) represents a common theme. Baldwin et al. defined *modularity* as the building of complex systems from subsystems designed independently to function as one whole unit (Bask et al., 2011). The focus of this dissertation is the application of OM and CMOs in particular. Consequently, introducing the perspective of modularity in an organization is inevitable.

OM involves dividing organizations into loosely coupled subunits with varying degrees of autonomy designed to undertake one or more production activity. This explanation underlies the definition of *OM* by Liao et al. (2010) and Zhang (2011), which I adopted for this dissertation with slight modification. Organizational subunits and departments are interchangeable as I show in subsequent sections.

Departments are units of the XYZ Company that undertake unique production and service activities with a certain level of independence. These departments are coupled, weakly or strongly, by the level of interaction and dependence on other departments within the organization. Departments that have a low level of interaction are less dependent on other departments; they are autonomous and are considered modular. I provide further explanation of modular and nonmodular departments with respect to the XYZ Company under the heading, Modularity in the XYZ Company.

Application of Modularity

The theory of modularity is applicable to equipment, products, organizations, and services. Product modularity refers to the application of modularity to product design and product development. Similarly, applying the principles of modularity to organizations based on organizational structure, and the level of interdependence of units within the organization, is referred to as organizational modularity (Bask et al., 2011; Liao et al., 2010; Zhang, 2011). Service modularity (SM) describes a unit of business functions of an organization. Evidence of modularity is readily observable in manufacturing systems, equipment, and highly integrated systems in which components are mostly modular (Kazemi, Rostampour, Azizkandi, Haghighi, & Shams, 2011). For example, a high percentage of motor vehicle systems consist of modular units; each unit performs specific tasks. The application of modularity to social matters is manifest in crowdsourced policymaking. Policymaking is divided into modules for better understanding and participation (Aitamurto & Landemore, 2015).

Positive attributes including cost savings, product variety, product improvement, flexibility, specialization, customization, interdependency coordination, and others are linked to the theory of modularity (Bask et al., 2011; Bask et al., 2010; Eklind & Persson, 2014; Gomes & Dahab, 2010; Jose & Tollenaere, 2005; Pekkarinen et al., 2008). Modularity enhances learning by allowing an incremental learning of subset of code in computer programming and provides parallel development—different groups working on subsets (Stol & Fitzgerald, 2015). Further, Granda, Nuño, García, and Suárez (2015) stated that modular design protocol supports interoperability, extensibility, and portability of platforms. Because modularity offers a certain level of independence and supports clustering of unique capabilities, it reduces bureaucratic tendencies, saving time and money, and it improves responses to customers. Consequently, the lead-time is improved (de Treville et al., 2014; Ghosh, 2013). For the same reason, modularized organizations are more flexible. Flexibility enhances the ability to offer customized solutions; this is the view by many including Bask et al. (2011), Zhang (2011), and Gomes et al. (2010). Katsaros, Tsirikas, and Bani (2014) also attributed positive organizational performance to flexibility.

Modularity has gained from the desire to automate systems to gaining competitive advantage in services, processes, and organizations. Services, processes, and organization are the main categories when discussing the modularity theory because any other endeavor does fall under one of these categories. Bask et al. (2010) called these categories the 3Ds of modularity. Proponents seem to indicate that the concept of modularity is the panacea to all industry problems.

Amid seemingly conclusive believes that applying the concept of modularity is useful to organizations, as noted above, Langlois (1999) contended that modularity cannot respond positively to all problems in the organization. Hutten (2015) stated that the limitations of modularity are unheeded, noting that modularity is a barrier to communication among units. Langlois claimed that a modular approach is not suitable in areas where highly specialized assets are a requirement. A disproportionate difference exists between the effect of modularity in products and knowledge-intensive business services (Cabigiosu, Campagnolo, Furlan, & Costa, 2015). Similar disparities also exist in the health services sector. Vähätalo and Kallio (2015) found that modularity might affect health services diversely. Effect of modularity also varies between technological modularity, interfirm coordination, and innovation (Hao, Feng & Frigant, 2015). Caution is needed with any proposition that assumes that the concept of modularity is always beneficial or nonbeneficial. A comprehensive assessment is necessary before implementing the concept of modularity.

Process Flexibility and Modularity

I examined three main variables for the convenience of the analytical method. It is probable that process flexibility (P_f) is influenced by modularity, but it was not a variable I considered for this dissertation. In previous sections, I noted that flexibility is a benefit of autonomy within a modular system. This section includes an explanation of the relationship between P_f and modularity.

The definition of *process flexibility* varies according to the subject. The perspective and meaning of P_f in this study focuses on time. *Process flexibility* is the number of discrete part types producible by a system per unit time (Sethi & Sethi, 1990; Tsourveloudis & Phillis, 1998). In a manufacturing system, P_f is a measure of discrete part types that a particular machine center can produce within a defined period. Accordingly, P_f relies on time and may benefit or suffer from the system's decision-making process. Autonomy, the ability to make decisions independently (Wang & Kumar, 2014), is relevant to process flexibility and derives from modularity.

Using the term *process flexibility* to characterize modularity is infrequent in the literature. However, the opposite can be said of *flexibility* as a standalone term and *autonomy*. *Autonomy* empowers organizations to operate independently as they pursue the satisfaction of their customers (Wang et al., 2014). By operating autonomously, managers can be flexible and quick in making decisions. The result is value maximization and the creation of competitive edge, according to Wang et al. The relationship between autonomy and modularity is relevant to the extent that the latter enhances decision-making and saves time. However, Wang et al. warned that the application and integration of modular techniques to flexible business process management could be problematic where clear understanding of the terminologies and how to use them are lacking.

Without embarking on statistical analysis, P_f as a function of time is potentially affected by modularity. The relationship between time and autonomy makes P_f a relevant variable for modularity and worth exploring as a variable in future studies. A study designed to examine the relationship between time and autonomy should benefit from using a mixed methods approach as it combines both a qualitative and quantitative study (Bryman, 2012; O'Cathain, Murphy, & Nicholl, 2010).

Modularity in the XYZ Company

Organizations modularize or outsource to gain competitive edge. Other strategies to achieving business advantage include acquisitions, capability reconfiguration, and collaboration with other organizations (Han, Porterfield, & Li, 2012; Kuo, 2011). Because CMOs have expert knowledge and are competent in specific areas and capabilities, they attract other organizations seeking to overcome those specific capability barriers. The focal company applies the concept of organizational modularity to keep up with demand. The XYZ Company defines *modularity* in terms of three complementary factors—degree of autonomy, level of interaction, and specialization. I explain each of these factors with particular focus on how they relate to modularity in the XYZ Company in the following paragraphs.

The *modular department* within the XYZ Company is autonomous compared to the nonmodular department and it has limited interaction with other departments. The *modular department* specializes in particular products. *Autonomy* describes the extent to which the modular department makes decisions concerning its internal affairs without influence from other departments. Because the *modular department* is fairly independent and service-specific, it has limited interaction with other departments. The *modular department* has a low level of interaction and interdependency; it is loosely coupled to other departments (Madhok, Keyhani, & Bossink, 2015). Subsequent paragraphs contain a brief background and explanation of the XYZ Company.

The XYZ Company is a fabricator and assembler of flexible (nonmetal) industrial components such as paper guides, roller assemblies, blades, cleaning brushes, and toner bottle closures, drive hubs, and adhesive sealing gaskets. Since its founding, the XYZ Company has grown in size and capability, expanding into other markets around the world with a strong presence in the converter market, servicing various industries including transportation, household appliances, medical device, and the digital media markets. The XYZ Company is a supplier to major original equipment manufacturers (OEMs) and popular in the medical device startup space.

The XYZ Company has modular and nonmodular departments. The modular department is both decomposable and composable. *Decomposability* and *composability* are measures of separation and recombination of organizational units. Kazemi et al.(2011) defined *decomposability* as the process of breaking down units to perform discrete functions. The level of dependence of one unit on another within a system is an expression of the ability of the unit to decouple from the system or to recombine with another system (Langlois & Garzarelli, 2008; Yang & Tempero, 2007). For example, it is difficult for a more dependent unit within an organization to separate into a distinct entity.

I adopted the common definition of decomposability and composability. *Decomposability* is the ability of a unit within a manufacturing company to decouple from the organization to become an independent entity. *Composability* is the ability of a decoupled unit, an autonomous entity, to recombine with other departments to create a new and different entity. Both *decomposability* and *composability* further serve to illustrate the concept of OM. *Decomposition* results in subunits, of which reintegration could take various reusable forms (Chaieb, Jemai, & Mellouli, 2015). Measuring decomposability and composability is outside the purview of this study. Methods for measuring decomposability and composability exist in the literature. For example, the works of Kazemi et al. (2011) adopted a combination of latent semantic indexing (LSI) and the singular value decomposition (SVD) methods and techniques in measuring decomposability and composability. *Decomposability* and *composability* are illustrative tools and uses the principle of interdependence in explaining modular and nonmodular units of the organization.

Figure 1 and Figure 2 illustrate the level of dependency of both modular and nonmodular departments on other service units within the focal company. Figure 1 shows that the *modular department* depends on six other units. Figure 2 is the *nonmodular department* with dependence on 13 other units. Accordingly, the *modular department* interacts with fewer departments, is less dependent on other departments, and is decomposable and composable. Similarly, the *nonmodular department* interacts with more departments, is more dependent on other units, and neither decomposable or composable. Modularity varies according to the interdependency levels between units of organizations.

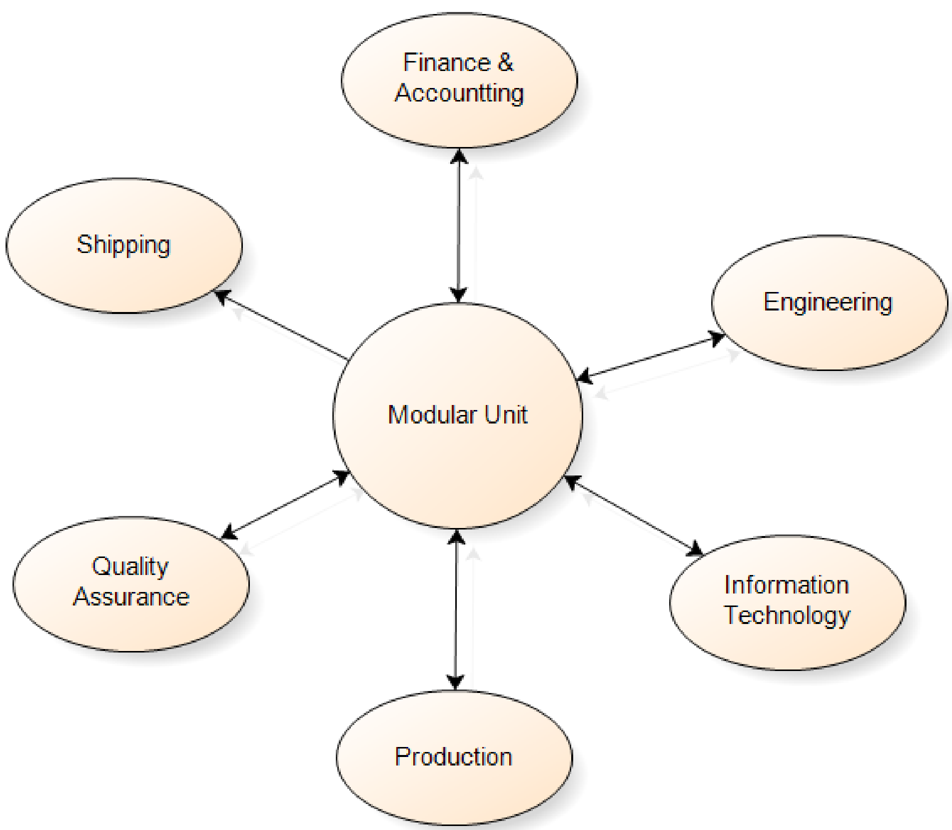

Figure 1. Modular unit: Digital media department with six dependent service units.

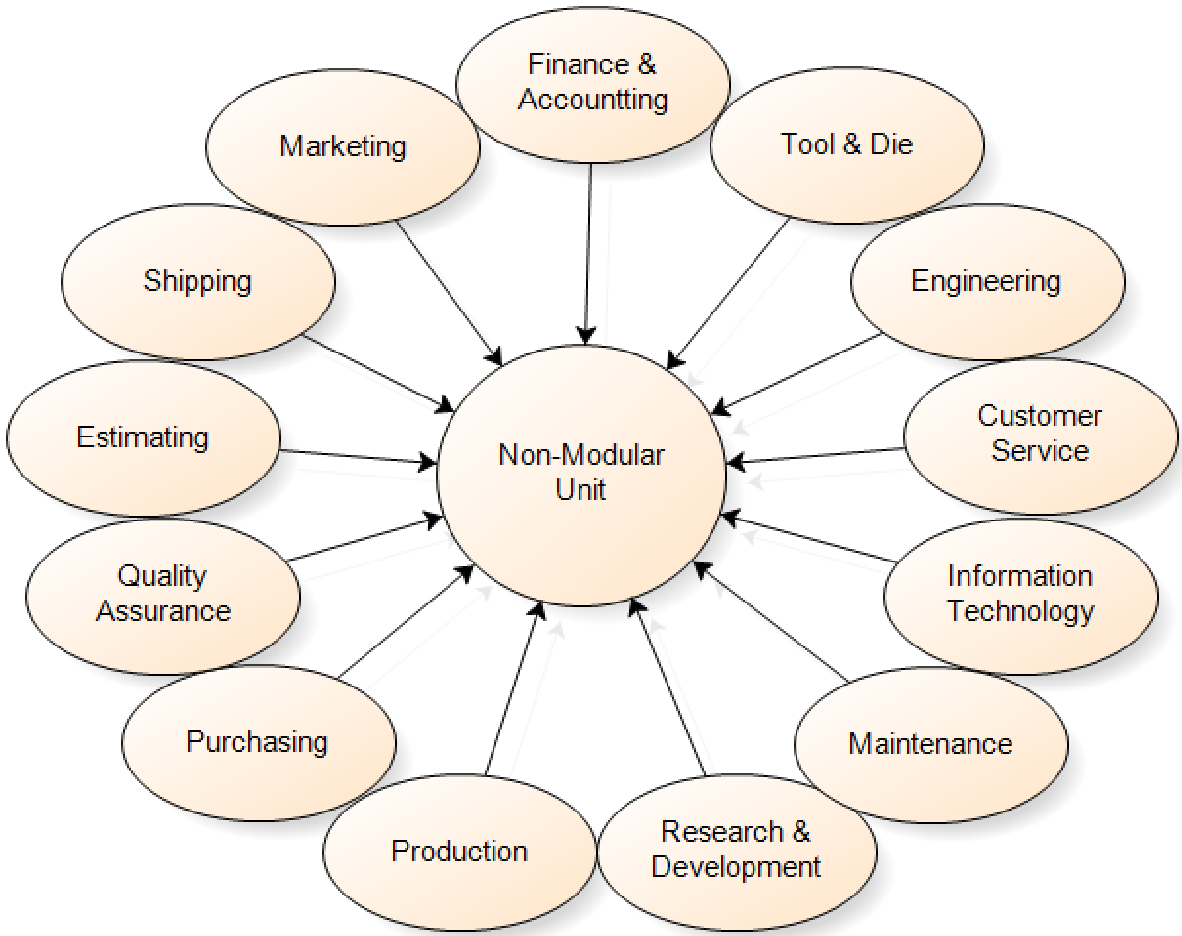

Figure 2. Nonmodular unit: Sales department with 13 dependent service units.

Problem Statement

I assessed the significance of modularizing CMOs using the XYZ Company as a case study. The XYZ Company is a suitable case because its organizational structure allows departments to operate at varying degrees of autonomy. Importantly, the XYZ Company has modular and nonmodular departments. The role of CMOs in the United States economy has increased in importance. The majority of small to medium size manufacturing companies—those with annual revenue of $7 million or less, according to United States International Trade Commission (USITC) Publication 4125 (2010) in the United States—operate as CMOs, contributing approximately $4.7 trillion to the U.S. economy in 2004 (USITC Publication 4125, 2010). Cavazos (2011) also stated that North American CMOs in the electronics sector alone earned projected revenues of more than $45 billion in 2011. According to GBI Research (2013), the global pharmaceutical CMO market grew at a compound annual growth rate (CAGR), of 10.7% from $21.2 billion in 2008 to $26 billion in 2010 and forecast a revenue growth of $59.9 billion by 2018. Similarly, Han et al. (2012) reported that global electronics CM would be worth $327 billion by 2014 with the United States accounting for approximately 21%.

The list of studies involving the theory of OM is long. The problem was that few studies have assessed the significance of OM in the context of a specific CMO. This research addressed this gap by assessing the significance of modularity by comparing two departments representing modular and nonmodular organizational units.

Purpose of the Study

The purpose of this quantitative quasi-experimental study was to assess if there is any significance in applying the concept of OM in CMOs. The strategy was to conduct statistical tests of significance of metrics including capacity utilization, profit margin, and efficiency between the modular and nonmodular departments while controlling for differences based on overhead cost and lead-time. A business decision is required to implement any concept in an organization, a decision based on thorough analysis and understanding. The result of this study provides decision makers in CMOs, some implications of implementing the concept of OM.

Demand for CMOs exist across industries including computer electronics, aerospace, defense, energy, pharmaceuticals, medical, and automobile manufacturing as well as OEMs seeking cost savings (Han et al., 2012). The importance of CMOs is thus high; therefore, a study assessing the significance, if any, of modularizing CMOs is desirable in many respects. I expect that policy makers in CM companies find the results from this study useful for improving decision-making.

Research Questions and Hypotheses

The research question for this study was:

What might be the significant value of implementing organizational modularity?

The hypotheses to test, definition, and explanation of the measurements of the variables for this study were as follows:

Ho_1: There is no significant difference in capacity utilization between the modular and nonmodular departments when controlling for differences based on overhead cost and lead-time

Ha_1: There is a significant difference in capacity utilization between the modular and nonmodular departments when controlling for differences based on overhead cost and lead-time.

Ho_2: There is no significant difference in efficiency between modular and nonmodular departments when controlling for differences based on overhead cost and lead-time.

Ha_2: There is a significant difference in efficiency between modular and nonmodular departments when controlling for differences based on overhead cost and lead-time.

Ho_3: There is no significant difference in profit margin between modular and nonmodular departments when controlling for differences based on overhead cost and lead-time.

Ha_3: There is a significant difference in profit margin between modular and nonmodular departments when controlling for differences based on overhead cost and lead-time.

Theoretical Base

Organizational modularity theory (Alexander, 1964; Simon, 1962; Williamson, 1975) is the grounding theory of this dissertation research. As I established in previous sections, the fundamental theory of OM derives from the combination and separation of elements to create new and more complex systems or other output variations (Rahikka, Ulkuniemi, & Pekkarinen, 2011). This feature exists in complex mechanical systems where components form subassemblies with separate functions; the subassemblies, in turn, integrate to form a more complex system. The theory of OM applies to organizations in the same manner; modular departments within the organization undertake tasks with less dependency on other units in the organization. Because these departments depend less on other units within the organization, they are decomposable and composable with relative ease.

Global competition demands flexibility in manufacturing processes. CMOs strategize based on the notion that product variety resulting from knowledge, technology, and experience sharing can be more economical (Liao et al., 2010). Hence, the emphasis on modularity— means to decompose systems into discrete subunits, to enhance flexibility. At the product level, modularity offers flexibility if subunits are swappable and recombinable to form a manufacturing system. Organizationally, modularity relates to units and their respective levels of independence. To the extent that units of organizations have limited interdependence or autonomy, a certain level of flexibility affecting performance do exist. This dissertation exploits the autonomy factor within CMOs by comparing certain performance measures in a unit with higher autonomy, the modular unit, and the less autonomous or nonmodular unit, for significance. I considered three performance indices for this study—capacity utilization, efficiency, and profit margin. I assessed the incentive for a CMO to implement organizational modularity using overhead cost and lead time as the control variables.

Nature of the Study

A quantitative research method was necessary for testing the significance of differences with measurable variables (Babbie, 2012; Morgan, 2015). The objective was to provide answers to the questions posed in the form of hypotheses as listed in the subsequent sections. I treated two departments of the XYZ Company, one modular and the other nonmodular with the variables and analyzed for statistical significance. The variables considered for this dissertation are capacity utilization, profit margin, and efficiency. The covariates are overhead cost and lead-time.

Archival data from the XYZ Company was used for this study. I did not have any influence on archival data because it already exists. The data, covering a period of 5 years beginning from 2008, included records of work orders and related documentation residing in the company archive. Data retrieval method complied with the XYZ Company standards.

Definition of Terms

The variables and other terms are defined and explained in this section. The variables considered for this research are capacity utilization, efficiency, and profit margin. The key independent variable is whether the department is modular or nonmodular and key covariates include overhead cost and lead-time. Subsequent paragraphs contain the definition and explain the planned measurement of each variable.

Capacity utilization (*CU*): In the context of this dissertation, capacity utilization is the ratio of the parts that the machine actually produces to the number of parts that the machine was capable of producing per unit time. CU expressed as a percentage by multiplying its ratio by 100.

$$\text{Capacity utilization}\,(CU) = \frac{n}{N} * 100 \text{ - } (1),$$

where N = the number of parts that the machine is capable of producing per hour (a machine-rated capacity) and where n = the number of parts produced per hour. The number of parts produced per hour was available from records of jobs.

Efficiency (E_f): The ratio of the actual time (T_a) it took to complete a manufacturing activity to the planned time (T_p); the ratio is multiplied by 100 to have efficiency expressed as a percentage.

$$Efficiency(E_f) = \frac{T_a}{T_p} * 100 \text{ - } (2),$$

The data are derivable from the work packet. The work packet contains manufacturing activities with planned times and production log of actual times of completion. The XYZ Company establishes planned times at the initial stage of bidding for the contract. Planned times vary according to machine center and the production activity, and are available in the job quote.

Lead-time (*LT*): The time from the order entry to the time that the order was closed (Sjøberg, Johnsen, & Solberg, 2012). LT is from the data source and does not require calculation; it is a control measure.

Modularity theory: Describes the extent to which subunits capable of independent function of a system are separable and recombinable to create entirely new systems without losing subunit level capabilities (Pekkarinen et al., 2008; Schilling, 2000).

Organizational modularity (*OM*): Refers to organizations in which their structures consist in weakly held departments. The departments have relative autonomy to operate and make decisions; they can decouple or recombine to create new entities with ease (Bask et al., 2011; Liao et al., 2010; Orton & Weick, 1990; Zhang, 2011).

Overhead cost (*OC*): The cost of direct labor plus factory overhead, which was used as a control measure (Kren 2014; Sjøberg, Johnsen, & Solberg, 2012). OC was taken directly from the data source and does not require calculation.

Product modularity: Describes a product that owed its existence to the assembling of separate and interchangeable components (Pekkarinen et al., 2008).

Profit margin (*PM*): The net profit divided by sale price. Profit margin is expressible in percent by multiplying the value by 100. The data for calculating profit margin for a job are obtainable from a job quote and the corresponding work packet.

$$Profit\ margin\,(PM) = \frac{Net\ Profit}{Sale\ Price} * 100 \text{ - } (3),$$

where Net Profit = Sale Price - Cost

The XYY Company used software to analyze completed jobs for profit and loss. In the absence of the software, manual calculation of profit margin is doable by using data from job quotes and finished work packets. For example, a job quote contains cost of raw materials, each production step with associated cost per labor-hour, and the sale price, and the work packet contains the actual time taken to complete each manufacturing activity. Actual cost consists in raw material cost and labor cost. The labor-hour cost varies according to the machine center and includes some overhead cost. Actual cost and profit margin calculations use data from company sources.

Service modularity: The breaking down of service or process into elements capable of offering single service characteristics. A service element is the smallest indivisible unit of service (Kazemi et al., 2011; Pekkarinen et al., 2008).

Assumptions

It is important to emphasize the fact that interaction and autonomy characterizes modularity and formed the foundation for the assumptions for this study. The assumptions for this study were (a) the level of interaction between departments and the autonomy exercised by each department, when combined, is a sufficient criterion for the identification and classification of modular and nonmodular departments, and (b) both modular and nonmodular department's archived data is enough to provide a result of significance, if any. These assumptions provided a better focus and the analyses that were necessary to respond to the research question.

Scope and Delimitations

The analysis portion of this study includes only archival data from the XYZ Company. The data, covering a period of 5 years beginning from 2008, included records of work orders residing in the company archive. The primary data was limited to data from modular and nonmodular departments. This study included peer-reviewed articles and gray literature in developing the background and supporting the over-arching theory of OM.

Job similarity across modular and nonmodular departments was not a criterion for selecting archival data for analysis. The assumption was that comparing the process of making products in a modular and nonmodular department will illuminate significance if present. The process of selecting jobs from the population of modular and nonmodular was random and could potentially enhance generalization.

Limitations

There are multiple limitations of this study. First, this study only includes one organization. Second, using one organization limits the extent to which findings are generalizable. Third, the focal company belongs to an industry group that lacks uniformity in practice standards. The lack of a standardized practice also means that conclusions from this study may only be cautiously generalizable. Finally, OM was not measured in this study; instead, it included the significance if any, in implementing the concept of modularity in a CMO.

Significance of the Study

Significance to Theory

The lack of empirically based research on the practice and theory of modularity in the contract-manufacturing (CM) domain, suggest that the theory of modularity is less popular as the literature seems to portray. This study may premier the introduction of OM to CMOs. There is support for OM as an alternative practice for improving organizational survivability in the face of global competition. For example, Gomes et al. (2010) and Liao et al. (2010) asserted that OM is a cost saving tool.

Significance to Practice

Data from the USITC corroborates the fact that the United States economy has become more reliant on CMOs. Consequently, it is imperative for CMOs to adopt practices that have the potential to support their growing prominence in the economy. Modularizing an organization is a valuable practice for enhancing flexibility and competitiveness (Güttel, Konlechner, & Trede, 2015). This study affirmed the significance attached to the practice of OM within the context of CMOs and add a survivability tool to the toolkit of CMOs. This body of work provides empirically based data upon which leaders in CMOs may rely in deciding for or against the implementation of modularity practices.

Significance to Social Change

CMOs are contributing to a high percentage of the revenue in the United States. Consequently, the reliance of the United States economy on CMOs is increasing (USITC Publication 4125). Given the high number of CMOs today, it is a positive social change if CMOs make appropriate use of modularity to produce better products at a reasonable cost and with increased manufacturing flexibility thus benefitting their customers, as well as themselves.

Summary and Transition

The literature supports the implementation of the concept of modularity in organizations. The view of many in the industry including scholars is that the practice of OM is positive, and it is a tool with which to achieve a competitive edge. However, caution is needed not to assume that modularizing an organization will solve all problems. Caution is required because there has been no study on the significance of implementing the concept of OM in CMOs.

This study is a quantitative quasi-experimental study designed for the assessment of the significance if any, in implementing the concept of OM in CMOs. The purpose of this study was to conduct statistical tests of significance using metrics including capacity utilization, efficiency, and profit margin, and covariates including lead time, overhead cost between the modular and nonmodular departments. Archival data from the XYZ Company is the source of data. Chapter 2 includes the literature review.

Chapter 2: Literature Review

This research aimed to assess the significance of modularizing CMOs. The literature revealed that the theory of modularity is not popular among those who drive policies and manage CMOs. Knowledge about the significance and importance of modularizing CMOs is lacking. Consequently, the goal of this quantitative study was to help contribute to research on the significance of modularizing CMOs by statistically analyzing productivity metrics between modular and nonmodular departments in a CMO. This review of the literature covers the theoretical foundation of modularity, and I end the chapter with a summary and transition section.

Modularity is a way to understand and approach the organization of complex systems, first introduced by Bemis in relation to architectural theory in the 1930s. In 1957, IBM applied modularity to the field of computer science by creating the Standard Modular System (Russell, 2012). Simon (1962) then refined the concept, and, from there, modularity has spread as a way to understand and approach organizing complex systems of all kinds—including technical, social, and economic (Sanchez & Mahoney, 2013). In essence, modularity is a way of ordering a system into self-contained and separable units that are able to function independently and that are able to be decoupled and recoupled within the larger system architecture for specific purposes. Despite the age and popularity of the theory of modularity, it is inccurate for researchers to assume that decisionmakers and policymakers in the manufacturing sector specifically recognize the concept of modularity as a tool to gain a competitive edge. This research provides substantial knowledge of modularity and the significance and importance of modularizing CMOs.

Schilling et al. (2001) had long made the call for more studies applying the theory of OM to CMOs. Schilling et al. called for extending the study of modularity to CM. Liao et al. (2010) recommended the expansion of studies on modular perspectives to better understand the effect of modularity. Studies involve the theory of OM exist, but few assess the significance of this concept in the context of a specific CMO. This research may fill the knowledge gap, but increasing reliance of the economy on CMOs makes this study even more important and urgent. The growth in CMOs will continue as OEMs seek cost savings (Han et al., 2012). The importance of CMOs is, thus, high. Therefore, a study assessing the significance if any of modularizing CMOs was desirable. This research affirms the significance associated with the practice of OM in the context of CMOs, thereby providing the needed knowledge.

I reviewed the research literature on types of modularity, drivers of modularity, and key variables of modularity. I also addressed proximate concepts: agility and flexibility. Proximate concepts share characteristics with modularity in the field of manufacturing. The following sections include the literature search strategy, theoretical foundation, review of the literature, and summary and conclusions.

Literature Search Strategy

To be comprehensive, I employed two search strategies: (a) search for the popular terms associated with modularity, and (b) search for less popular and less likely terms. The search for the less popular and unlikely terms became useful when obvious terms linking modularity and CM was exhausted. Using the first strategy, I searched for terms and phrases commonly associated with modularity in relation to CM in academic databases. The familiar terms included *modularity*, *modularity theory*, *organizational modularity*, *contract manufacturing*, *benefits of organizational modularity*, *process modularity*, *process flexibility*, *origin of agility*, *supply chain modularity*, *strengths and advantages of modular organizations*, *service modularity*, *modularity in the organization*, and *drivers of modularity*. I used recent references, less than 4 years old, wherever possible and restricted the use of older references to areas where historical perspectives were of relevance and significance.

The other approach was to search terms and phrases that were not as common in linking modularity and CM. All of the terms searched using this strategy were *recomposition in modularity*, *recombination in modularity*, *modularity variables*, *origin and mechanisms of modularity*, *modularity in service*, *attributes of organizational modularity*, *criteria for modularity*, *why modular organization?*, *modularity and contract manufacturing*, and *cost advantage of modularization.* This approach yielded pertinent, timely, peer-reviewed articles, as well as other materials used for general information on the subject.

I accessed the academic databases through the Walden University Library home page. The academic databases were: the Thoreau multiple database, ABI/INFORM Complete, Business Source Complete, Academic Search Complete, Emerald Management Journals, expanded Academic ASAP, and Science Direct. I searched Google Scholar as well. The Walden University Library also offered the Document Delivery Service (DDS), an exchange program, which allows the exchange of documents and files between institutions. I used the DDS to gain full access to many of the articles found.

Theoretical Foundation

The overarching theory of this research is modularity, which has its foundation in the management of complex systems, a method first espoused by Bemis in the 1930s. Simon (1962) developed the use of the theory. Simon stated that a complex system is better managed in smaller units, and that these smaller units, which are capable of performing distinct, discrete functions, can be recombined within the larger system architecture system. *Complex system* is defiend as composed of a large number of parts interacting in a nonsimplistic way. Breaking down of complex system into smaller—manageable modules is fundamental to the explanation of the modularity theory (Matos & Petrov, 2015). Experts have applied the modularity theory in many fields for various reasons. Some areas of application of the theory include computer science, management studies, evolutionary biology, educational theory, and manufacturing sectors (Park, Chen, Wang & Deem, 2015; Russell, 2012). Some of the developments attributable to the theory of modularity in manufacturing, for example, include increased organizational adaptability and flexibility, faster response to customer needs (Bask et al., 2011; Gomes et al., 2010; Sanchez et al., 2013), as well as more effective management of complex and uncertain systems (Chen, 2002; Gomes et al., 2010; Valle, Avella, & Garcia, 2011). Although researchers recognize the need for more critical work on modularity, many see that implementing the principles of modularity can be a good investment for an organization as it can allow organizations to be more able to adapt to market fluctuations and technological change (Zhang, 2011).

Two main characteristics of modularity are the ability to break down the system into individual subsystems with discrete functions and the recombination of the subsystems into a new system. Madhok, Keyhani, and Bossink (2015) and Simon (1962) noted that loosely coupled subsystems have these characteristics. The immediate consequence of loose coupling of subsystems is flexibility and responsiveness; they offer the ability to decouple and recombine as desired to meet required system objectives (Rahikka et al., 2011; Sanchez et al., 2013). These characteristics are also indicative of the independence of subsystems within a modular system.

The outcomes of modularity have gained some degree of credibility and, thus, modularity warrants attention for possible practical application to a wide array of organizations, products, and services. The practice of modularity follows a simple nomenclature that is reflective of the sector of application. For example, *organizational modularity* (*OM*) is the application of the theory of modularity in an organizational structure. Similarly, we have product modularity, SM, process modularity, as well as others. The definition of modularity is reflective of the applicable discipline or sector. I address types of modularity in a later section.

The principles of OM relate directly to the subject of this study, the XYZ Company, and these principles provide a useful and important framework for this research. The XYZ Company consists of two major units: modular and nonmodular departments. Subunits of the modular department maintain a strong independence and have minimal interaction with other departments within the company. On the other hand, the subunits of the nonmodular department are more dependent on one another. The nonmodular department is a microcosm of the organization in which the departments cannot decouple or recombine with ease to form a new entity. In essence, the XYZ Company operates two systems and, therefore, lends itself to the present type of organizational study. The following sections examined the conceptual framework of the theory of modularity.

Literature Review Related to Key Variables and Concepts

In this section, I first reviewed the literature for key variables used in this research. Then I reviewed the literature on various concepts of modularity including types and drivers of modularity and concepts that are close to the theory of modularity also known as proximate concepts. I synthesized publications relevant to each concept and provided key statements and definitions. Each section includes a description of the previous application of the concept and its relevance to this research.

Variables

The literature showed that studying the effects of modular design on manufacturing performance employed several variables. The variables include those of agility, flexibility, profit margin, capacity utilization, and efficiency. The following variables in this study are: capacity utilization, efficiency, and profit margin. Overhead cost and lead-time are the covariates.

Capacity utilization. Past research used capacity utilization (CU) as a viable variable to measure the effects of modularity on manufacturing performance (Morin & Stevens, 2005; Ragan, 1976; Wang & Zhu, 2007). It is a variable in this study. CU refers to the quantity of output of a manufacturing system, and it is the ratio of the actual number of units that a machine produces to the maximum number of units that the machine is capable of producing. Although a search of the literature revealed that current studies employing CU as a variable to measure the effects of modular manufacturing are few, CU is a useful variable in the study of modular manufacturing.

In their 2010 study, Sun and Wong used CU as a key variable to analyze the economic effect of job-to-sales ratios in Taiwanese tourist hotels and airline sectors. For their purposes, Sun and Wong (2010) slightly adjusted CU for application to the service sector. Sun and Wong adopted occupancy rate as an indicator of CU for the accommodation sector (hotels); and load factor as an indicator of CU for the airline sector. For the accommodation sector, CU is the number of actual rooms occupied to the total number of available rooms (Sun et al., 2010). For the airline sector, CU is the ratio of passenger miles actually flown to the total number of seats available (Sun et al.). Their study had important implications for the service industry because it helped to clarify the underlying relationships between jobs-to-sales ratios and CU. Their result showed that labor efficiency was the most significant factor in determining the stability of the jobs-to-sales ratio (Sun et al.). The study focused on the service industry, but Sun and Wong's study showed that CU is a useful variable in the study of productivity and proves viable to this study.

Olhager and Johansson (2012) developed a framework for assessing long-term capacity management for firms that merge service operations and manufacturing into one system. They noted that the firms face capacity management challenges. Olhager et al.

merged capacity strategies on capacity management and planning strategies on service operations, and then mapped the manufacturing-based framework on two existing frameworks for service operations. The framework is useful for a single case study of an industrial manufacturing firm.

Efficiency. Efficiency is another variable used to measure the effects of modularity on manufacturing, though current studies using efficiency as a variable are few. Specifically, efficiency measures modularity's effect on manufacturing time and performance. Efficiency refers to the ratio of the actual time it takes to complete a manufacturing activity to the planned time for that activity. In his 2011 study assessing the performance of modularity to manage supply chains, Cheng hypothesized that a higher level of modularity associated with higher efficiency and profitability. Findings supported the hypothesis, and while results showed that modularity negatively affected product specialization, they indicated that modularity positively affects CU (Cheng, 2011).

Synergistic use of internal and supply chain resources enhances efficiency and optimal utilization. Cheng (2011) stated that improved efficiency and utilization was possible in a scenario where synergy exist between internal and supply chain resources. Supply chain may also benefit from the collaboration between suppliers and customers on modular product design (Dyck, Gordon, & Kung, 2014). In their 2010 study of modularity's effect on new product development (NPD) time performance efficiency, Danese and Filippini (2010) also found that product modularity and integration practices increased efficiency by reducing NPD time performance. The life of a modular product is longer because it is better adaptable (Cooper, Skelton, Moynihan, & Allwood, 2014). The design of modular product while still in the NPD process may be affected by supplier involvement (Yoo, Shin, & Park, 2015). Practical implications of their findings suggest that managers might simultaneously focus on inter-functional integration and product modularity in order to facilitate their interaction, rather than focusing on product modularity only (Danese & Filippini, 2010).

Lead time. Lead time (LT) is the period between the release of a new order to production and completion (Jacobs, Droge, Viakery, & Calantone, 2011). Recently, researchers have studied LT in relation to manufacturing agility (Jacobs et al., 2010), made-to-order manufacturing systems (Ioannou & Dimitriou, 2012), lean manufacturing (Ghosh, 2013), increased productivity (Shamsuzzoha, 2011), and demand volatility (de Treville et al., 2014). Similarly, modularity is a positive factor on launch speed in the presences of product platforms and manufacturing flexibility (Vickery, Bolumole, Castel, & Calantone, 2015).

Manufacturing LT refers to the elapsed time between committing an order to production and the time of completion and ready for delivery (de Treville et al., 2014). This may include the time required to receive parts from a supplier. Recently, researchers have studied LT as an operational metric in relation to agile and lean manufacturing. Ghosh (2013), for example, studied lean manufacturing in Indian manufacturing plants using LT as a performance measure. Lean manufacturing works on three levels: philosophical, systemic, and technical (Ghosh, 2013). Philosophically, lean manufacturing is about limiting waste in a production system (Ghosh, 2013). At a systemic level, a lean approach may involve designing or re-designing production systems to eliminate redundant motions and elements; it may also involve developing methods of systematic problem solving (Ghosh, 2013). Technically, lean manufacturing refers to a congregation of techniques, tools, practices, and applications aimed at decreasing waste (Ghosh, 2013). LT is a vital element of lean manufacturing, related primarily to systemic and technical levels of operation. Consequently, Ghosh (2013) used LT, as well as productivity and first-pass correct output, to measure lean manufacturing performance in automobile manufacturing plants located throughout India. Ghosh (2013) found that implementing lean manufacturing led to high productivity, decreased LT, and improved first-pass correct output. In addition, and interestingly, respondents to the study's questionnaire identified these operational metrics as the main drivers of implementing lean manufacturing in the first place. The use of lower levels of required time, space, machine, and energy improves profit (Tyagi, Choudhary, Cai, & Yang, 2015). However, researchers should consider the results and generalization of the study in relation to its relatively small sample size.

De Treville et al. (2014) studied the supply chains of three companies, focusing on LT cost in relation to demand fluctuations and volatility. De Treville et al. observed that researchers and decision makers agree that short lead times can improve competitiveness, but that they have had difficulty quantifying short LT benefits and the actual value of LT. Research has shown that the benefit of LT diminishes when salvage capacity is high, and demand is predictable (Blackburn, 2012). De Treville et al. (2014) used a real-options model quantifiably to measure the connection between demand unpredictability and LT value. Real option model is a business decision tool wherein a firm reviews its options and may invest in projects with potential for higher value in the future (Wong, 2007). In their study of three companies (Nissan Europe, GSK Vaccines, and Nestle Switzerland), de Treville et al. (2014), found that the value of LT increases with demand volatility. In addition, they found that managers in all three companies underinvested in cutting LTs because they underestimated mismatch costs (ostensibly functional products that end up requiring high market mediation) arising from LT. Although the study did not focus on modular companies, modularity has been shown to increase a company's adaptability to external volatility (Bask et al., 2011; Gomes et al., 2010; Sanchez et al., 2013). The study of de Treville et al. (2014) is beneficial for measuring the value of LT in relation to unpredictability of demand and for showing possible connections to LT and modular systems. However, more research on LTs is needed with respect to organizational performance.

Researchers have also studied LT in made-to-order manufacturing systems. For example, the study of Ioannou et al. (2012) focused on LT estimation in relation to material requirements planning (MRP) for made-to-order manufacturing systems. The objective of Ioannou et al. was to enhance the accuracy of manufacturing LT estimates using iterative algorithms rather than static lead-time estimates that is typical of MRP systems. Made-to-order systems are unique and require customer involvement and customization levels that necessitate longer LTs. Therefore; the traditional MRP systems are often inapplicable to made-to-order systems (Ioannou et al., 2012). Consequently, Ioannnou et al. created a method for adapting LT estimates to made-to-order systems through a decomposition algorithm by figuring the specific requirements of orders against the current state of the manufacturing system. The researchers did not study LT in relation to modular manufacturing specifically, however, because modularity encourages agility it may share certain levels of adaptability and flexibility with made-to-order systems and, consequently, may necessitate its own specific LT estimation methods. Exploring the connection between LT and modularity is a potential topic for future research.

Jacobs et al.(2011) considered LT as an element of manufacturing agility. In addition to customer responsiveness and quick delivery of goods, Jacobs et al. used shorter, more competitive LTs as an element of agility. *Agility* is the rapid and effective response to demand changes (Jacobs et al., 2011). Product modularity may lead to manufacturing agility by decreasing manufacturing LT. Agility is achievable by product decomposability wherein modules built in parallel without assembly problems can decrease LT (Jacobs et al., 2011). This positive connection between product modularity, manufacturing agility and decreased LT warrants more study. Shamsuzzoha (2011) also studied LT in relation to product modularity. Shamsuzzoha (2011) observed that product modularity could cut manufacturing LT through decomposability, addition or replacement of modules, to adapt to changing demands. This aligns with the findings of Jacobs et al.; however, Shamsuzzoha (2011) also argued that product modularity could also decrease product development LT. Organizations can reduce product development LT through modularization by creating product variants, by assembling and re-assembling different product module elements. Shamsuzzoha's study was important for its information on the connection between product modularity and manufacturing LT and also for the connection between modularity and product development LT.

Overhead cost. Manufacturing or production overhead costs (OC) include all production costs that do not relate directly to output (Kren, 2014). The costs of direct material and direct labor constitute direct output costs. In contrast, production overhead costs, or indirect production costs, can include rent or payment on the factory building, depreciation on the factory building and equipment, factory supervisors and quality control, factory maintenance employees, energy for factory operations (e.g., electricity and gas), and indirect factory supplies (Kren, 2014). The overhead cost to income ratio potentially yields a higher profit (ElKelish & Tucker, 2015; Khan, 2015). Because manufacturing overhead costs are indirect (i.e., there is no simple, direct, and unproblematic relationship between products and costs), they pose challenge to cost allocation, planning, and control (Bengu & Can, 2010). To date; however, researchers have not directly studied manufacturing overhead costs in relation to agile or modular systems and represents a gap in the research literature on modular manufacturing. However, recent research on overhead manufacturing cost includes study of areas that may have implications for modular systems. Examples are efficiency and manufacturing overhead (Kren, 2014), misapplied capacity (Snead, Stott, & Garcia, 2010), cost stickiness (Ghaemi & Nematollahi, 2012), and step-down methods for allocating OCs (Bengu et al., 2010).

Bengu et al. (2010) reviewed the primary criteria for selecting the allocation sequence in the step-down method of allocating manufacturing overhead costs. Because manufacturing overhead costs represent indirect costs, traditional direct or simple allocation methods used for the direct cost allocation are not suitable (Bengu et al., 2010). A common method for allocating indirect costs is the step-down method that consists of allocating indirect costs or costs from supplementary costs centers to other supplementary costs centers or to direct or primary costs centers (Bengu et al., 2010). The sequence typically starts from the cost center that serves the most benefit to other cost centers, and after allocated costs, the procedure continues according to this criterion, step-by-step, until the allocation ends. Bengu et al. (2010) observed that step-down allocation sequences may also begin from the cost center that has the highest amount of OCs, and step down from that point. A combined approach considers an allocation sequence that combines the two above approaches. Strategies for determining allocation sequences for overhead manufacturing costs are important considerations for the strategic cost management areas of organizations. However, researchers have yet to study whether modular and agile systems have their own specific considerations when figuring indirect and overhead cost allocation.

Researchers have also studied overhead costs in relation to misapplied capacity (Snead et al., 2010), cost stickiness (Ghaemi et al., 2012), and efficiency (Kren, 2014). For example, in their critical review of recent cost accounting textbooks, Snead et al. (2010) observed that textbooks do not address the in-depth issues concerning the causes of misapplied capacity cost (that is, under/over-applied fixed manufacturing overhead) in relation to manufacturing overhead costs. Most textbooks recommend reporting misapplied capacity as production volume variance and writing it off. Such a strategy may have important managerial and financial accounting reporting implications. Snead et al. (2010) recommended a strategy for determining the causes of misapplied capacity costs in relation to overhead costs that is more robust and responsive. This strategy included considering (a) capacity that is not planned to be used, (b) unused capacity with the potential to be used for anticipated growth in the long term, (c) and unused capacity with the potential to be used for reasons related to seasonality in short term. In another study, Ghaemi et al. (2012) examined direct labor and materials costs in relation to overhead cost in companies on the Tehran Stock Exchange and found that while the direct costs of materials and labor were sticky, overhead costs were not. Stickiness refers to cost behavior wherein by increasing sales revenue, costs increased faster compared with the reduction of sales revenue, which is equivalent to the increase in sales revenue. For example, costs are sticky if sales revenue increased by 10% and costs increased by 9%, but sales revenue decreased by 10% (equivalent to rate of increase), and costs decreased by 8%. Also, in his study of value and efficiency in OCs management systems, Kren (2014) reviewed current research and found that a majority of organizations continue to rely on standard costs management systems for cost management information even though they may be implementing manufacturing innovations that may require new or modified cost management methods. Kren (2014) recommend use of a method change variance that separates engineering efficiency improvements from the typical causes of OC variances, thereby helping to maximize value. This approach might apply to manufacturing innovations such as modularity as well. The above studies represent recent research that has successfully used overhead cost planning and control, and they suggest that researchers might use OC in the study of modular manufacturing systems as well.

Profit margin. Profit margin is the ratio of the net profit to the sale price. The use of profit margin specifically as a variable in studies involving modularity and manufacturing is limited. Konstantaras, Skouri, and Papachristos (2009) studied how modularity might affect profit maximization through return policies for producers of build-to-order (BTO) products. The study recommends that the profit maximization model include the selling price as an additional decision variable of the BTO item. The model created salvage value by adopting a modular design -the assembling of new products by using parts from returned ones. In this study, profit margin is a variable that assess differences in performance of modular and nonmodular departments.

Concepts

The concepts reviewed in this section are close or proximate concepts, to modularity to the extent that they share certain characteristics with modularity. For example, the concept of modularity has led to flexibility and agile systems. On a narrow view, agility and flexibility may be confused with modularity and requires delineation. The following are explanation of the concepts of modularity, agility, and flexibility. Explanation for the concept of CM is part of this section. An explanation of the methods of implementing modularity also forms part of this section.

Modularity and types of modularity. There are different types of modularity, and the application of the concept of modularity follows a naming system that reflects its sector of application. For example, organizational modularity is the application of the theory of modularity in an organizational structure. Similarly, we have product modularity, SM, and process modularity. Because the modularity theory applies in many disciplines, the definition of modularity is reflective of the particular discipline or sector of application. This section reviews two types of modularity relevant to this study, two of the more pertinent and studied types of modularity: organizational modularity and product modularity.

Organizational modularity. Organizational modularity is a kind of organizational structure built upon and distinguished by the ideas and principles of modularity. Benassi (2009) listed certain characteristics that have come to distinguish modular organizations. Chief among these is an organization's very modularity itself, its modular composition, its ability to decompose, or rearrange its self-contained units within the larger system architecture for specific reasons. These designed units are efficient, flexible, and easily de- and re-coupled, and maintain a high level of autonomy in responsibility and decision-making (Benassi, 2009). Because modules can function both independently and or within the larger integrated whole, modularity makes complexity manageable (Gomes et al., 2010). Benassi (2009) observed that because of their adaptability and agility, modular organizations are particularly well suited to the rapid changes of high-technological markets.

Modular organizations have a positive effect on manufacturing performance and supply chain management. For example, in their large-scale empirical study, Liao et al. (2010) found that a combination of modular organization and system integration can help firms to achieve greater performance, citing that a firm's absorptive capacity facilitates better use of system integration and modularity practices. Several studies exist, in supply chain management, of the characteristics of flexibility and agility of modular organizations to utilize production capacity, diversity product offerings, and allocation of network capital (Cheng, 2011). Cheng's study, for example, found that modularity had a positive effect on CU, return on investment (ROI), and return on assets (ROA). Consequently, organizations are restructuring the designs of their supply chains in order to more effectively bundle and unbundle resources, and better coordinate flow (Borjesson & Hölttä-Otto, 2014; Gomes et al., 2010).

Other studies including the performance of partially modularized organizations also exist. In their 2009 study, Gentry and Elms noted that not all firms are able to achieve full organizational modularity, and that while modular theory recognizes this, empirical research literature has tended to dichotomize modularity: firms have been identified, and consequently studied, as being either modular or not. What Gentry and Elms (2009) called for was more research on modularity conceived of as a continuum and, consequently, empirically studied the effects of partial organizational modularity on performance in the electronic manufacturing services (EMS) industry. Using fixed effects regression analysis to analyze archival and data from surveys of 260 firms, Gentry et al. found that the more firms relied on partial modular arrangements, the lower their performance, due to complications in factors (communication and coordination) associated with increased inter-dependency. Lower performance due to increased inter-dependency runs counter to the principles of modularity, and Gentry and Elms' findings suggest that partial modular organizations, at least in the EMS industry, do not perform as well as those fully modularized. Gentry et al. concluded by calling for more empirical research in the area of partial modularity in order to add to their findings on performance in partially modular organizations.

Overall, OM shows a significant positive effect on organizations. Zhang (2011) noted that organizations could benefit from modular design because modular organizational design can improve an organization's internal mechanisms of value innovation. The competitive advantage of OM includes decreasing costs, flexible response to the market and technological change, and fully utilizing external sources. Further, Sanchez et al. (2013) observed that organizational modularity displays several characteristics of foundational importance to the organization of, for example, economic activities, including greater flexibility and adaptability than systems without modular organizational design.

Product modularity. Modularity as it relates to product design, development, and distribution is another important type of modularity. Product modularity is an effective response to the need for increasing variety in the marketplace, without adding the costs of increased variety in the enterprise (Borjesson et al., 2014). Product modularity reduces new product development (NPD) cost, speed up NPD, and enhance consumer customization (Jacobs, 2010). The architecture of product modularity consists of component modules with standardized interfaces that allow the interchange of various versions or sizes of a module; this kind of flexibility results in the potential benefits of variety listed above (Borjesson et al., 2014).

Still, several researchers observed that product modularity require more specific and critical work. Danese et al. (2010), for example, noted that firms could use product modularity strategy to increase product variety and shrink the NPD process. Empirical studies confirming this remain scant, but the study of Danese et al. (2010) demonstrated that (a) product modularity could have a positive direct affect on NPD time performance, and (b) integration moderates positively the product modularity-time performance relationship. Boer (2014) declared that most literature on modularity touts benefits that do not always have the necessary empirical backing. Boer (2014) called for specific work including operationalization of product modularity and more study detailing the linkage between firm performance and product modularity.

Jacobs (2010) also noted that empirical evidence supporting the claims that modular product architecture increases the NPD time and decreases NPD cost is scarce. Working from general modular systems theory (GMST), Jacobs' (2010) study on modularity's effects on manufacturing agility and firm growth performance found some, albeit qualifying, empirical evidence to support the above claims. The study showed, for example that product modularity positively and directly affected firm growth performance, process modularity, and manufacturing agility (Jacobs, 2010). The study further showed that product design modularity is key to understanding GMST effects regarding how changes in one system affect changes in other systems (Jacobs, 2010).

In their study of product modularity, Kamrad and Schmidt (2013) noticed that despite the advantages that modularly upgradable products offer to consumers, companies produce fewer modularly upgradable consumer products. Because a modularly upgradable product allows consumers to keep up with technology, by replacing components or modules rather than replacing the entire unit, a firm's development, and production costs may decline. Kamrad et al. (2013) observed that the firm under study had what the researchers characterized as a two-pronged strategy: an integral upgrade strategy and a modular upgrade strategy. In this two-pronged strategy, each generation of product has a new design and offers component upgrade. What the researchers found was, in fact, a trade-off. The value of modularity decreases with the overall rate of innovation in component technologies, while the value of modularity increases with the differences in improvement rates between components.

There are significant studies on modularity as it relates to product global performance and platform-based product design. For example, Thomas (2014) noted that platform-based product design is another area lacking in empirical research. More research in this area is important because the NPD and product design process are sources of strategic flexibility that can lead to a firm's competitive advantages in turbulent economic environments. Thomas (2014) found that more firms turned to platform product designs in turbulent times and the higher the degree of platform design, the higher the level of performance in the market. Ultimately, strategic flexibility based on modularity partially, yet positively, mediated the relationship between performance and platform design.

Caridi, Pero, and Sianesi (2012) observed that there was no scholarly consensus on the effects of product modularity on supply chains. The study of Caridi, Pero, and Sianesi investigated whether choices of supply chain management depend on product modularity and innovativeness, and the alignment of product features and supply chain decisions to increase performance. Caridi et al. (2012) used a medium scale survey of 54 Italian furniture businesses to address their research questions, and they employed factor and cluster analyses to assess data collected. The results showed that both product modularity and innovation significantly affect supply chain operations. The practical implications are that product modularity and product innovation are necessary considerations in supply chain design and management.

In another study, Yin et al. (2014) examined how product global performance affects the choice of product architecture through the NPD process. Yin et al. classified three types of product architecture: modular (elements able to function separately), integral (elements share functions), and hybrid (contains attributes of both modular and integral). The study revealed that while existing research shows that the choice of product architecture through the NPD process is a critical decision for a manufacturing firm, no one architecture is optimal in all cases (Yin et al., 2014). The research further adds to the literature on product modularity by developing analytical models to obtain a product's global performance through modular, integral, hybrid architectures, and analytical models that are required to recognize and consider particular trade-offs related to the choice of architecture under various circumstances.

Agility and flexibility. Two concepts that are close to modularity are agility and flexibility. Agility and flexibility are common in the field of manufacturing. Direct organizational consequences of modularity include increased organizational adaptability and flexibility to external forces and faster response to customer needs (Bask et al., 2011;

Gomes et al., 2010; Sanchez & Mahoney, 2014). An organization's agility and flexibility pertain to how it responds internally to external forces: to customers (customization) and to market and technological change. Modularity allows for agility and flexibility in these areas and facilitates an organization's appropriate internal responses.

Agility and flexibility derive from the two main characteristics of modularity: the ability to subdivide a system into individual subsystems with discrete functions and the recombination of the subsystems into a new system. Subsystems have to be loosely coupled to achieve these characteristics. Loose coupling of subsystems occur if they maintain functionality while retaining different identities and the ability to be separated (Simon, 1962). The immediate consequence of loose coupling of subsystems are flexibility and responsiveness; they offer the ability to decouple and recombine as desired to meet required system objectives and customer response (Rahikka et al., 2011; Sanchez et al., 2014). In addition, Zhang et al. (2009) observed that flexibility and agility are strategies that are imperative for firms to cope with uncertainty.

Bask et al. (2011) observed that in today's highly competitive markets, a firm's business excellence is oft times defined by its response to customer needs and its flexibility. They noted, however, that while mass customization, significantly enabled by modularity, has become a popular production strategy for achieving cost-efficient customization, little is available as alternative to such mass customization. Furthermore, they noted that it is important to be able to recognize when mass customization is a viable option and to realize that despite its broad appeal it is not a one-size-fits-all strategy (Bask et al., 2011). Their research helps in this regard, as it introduces a framework and systematic approach for analyzing different aspects of customization SM, including customer service offerings and service production processes and networks.

Agility and flexibility also have significant implications for the manufacturing sector. Jacobs et al. (2011), for example, used structural equation modeling to study the effect of product and process modularity on manufacturing agility and firm growth performance. Jacobs et al. (2011) found that product modularity positively and directly affected manufacturing agility, process modularity, and a firm's growth performance. This study is important because it supplies empirical evidence of the influence of one element of a modular system to assist a fit between the firm's manufacturing and product strategies and directly drive system performance (Jacobs et al., 2011). Zhang et al. (2009) studied product flexibility, specifically product concept flexibility, as it relates to manufacturing and customer satisfaction. The study showed that firms with low product concept flexibility were less likely to benefit from prototype flexibility than with high product flexibility (Zhang et al., 2009). In addition, product prototype flexibility and product concept flexibility act additively to predict customer satisfaction (Zhang et al., 2009). This study is significant because it adds to the research on flexibility and manufacturing that helps to identify and rectify issues in the development stage that may lead to problems in the downstream implementation phase.

Sanchez and Mahoney (2014) noted flexibility and agility in slightly different terms, though the perceived benefits for organizations are similar to those listed earlier. They stated that the fundamental design difference between modular and nonmodular systems involve flexibility and agility; modular systems are dynamically optimized to adapt to multiple purposes and changing conditions, while nonmodular systems are typically statically optimized to meet a single purpose and static conditions (Sanchez et al. 2014). Flexibility and agility, then, are forms of strategic modularity, which involves strategic partitioning of the system architecture (Sanchez et al., 2014). The design can be decomposed to initiate the most strategically effective range of response to said force or factor (Sanchez et al., 2014).

Other forms of manufacturing apply agility and flexibility in relation to modularized enterprises. For example, continuous process enterprises—manufacturing methods that run without interruption—demonstrate differing characteristics in relation to manufacturing flexibility when compared to modular enterprises (Xu, Du, Zeng, & Li, 2013). Although there are research on flexibility and modularized enterprises, there is little on flexibility in relation to continuous process enterprises. Xu et al. (2013) sought to help fill this gap in the literature as the researchers develop a theoretical basis for explaining the flexible manufacturing problem of continuous process enterprises with multiple products. This study is relevant to this research only to the extent that it serves as an example of flexibility as a proximate concept and as a useful concept in the study of other manufacturing designs. In this case, it is the continuous process enterprise.

Drivers of modularity. Implementing the concept of modularity is an investment and a business decision that organizational policy makers must make. Like any other investment decision, organizational leaders seeking to implement modularity must justify the expense. This section explains the rationalizations for adopting the concept of modularity. These are the drivers of modularity.

Organizations adopting modularity may offer different reasons for their actions, but they all have a common rationale: mostly motivated by changing business circumstances and technological innovation. According to Ernst (2005), the concept of organizational modularity is a response to economic and competitive market change. This section reviews the literature for factors capable of causing policy—and decision-makers in organizations to consider the implementation and practice of modularity. In essence, this section includes the drivers of modularity within organizations, specifically those of competition, standardization, and customization, advancement in technology, emulation and outcome, and cost advantage.

Market competition. One of the biggest drivers of modularity involves the pursuit to remain competitive in new and changing business environments. Changes in technology and business are constantly exerting dynamic forces on the market (Sharifi & Zhang, 1999). These forces compel organizations to adapt by evolving new tools and new strategies to stay competitive (Cheng, 2011). To remain competitive, especially in the twenty-first century, entities must be able to adapt to continuous change, to ensure quality improvement, and to respond to social responsibility.

Competition and the quest for customization have driven manufacturing organizations to apply the theory of modularity to the management of supply chains (Cheng (2011). The advantages, perceived or real, of organizational modularity, lends it credence as a means to gain a competitive edge. Cheng (2011) noted the advantages of modularity include agility (adaptability) and the flexibility to recombine inputs to offer more diversified products, high production capacity utilization, and better network and capital asset allocation. The combination of these factors offers increased flexibility to delivery of customized products and the ability to stay competitive. Cheng's (2011) findings are important because they help determine the effectiveness of using modularity in the coordination of complex supply chain, linking modularity and agility to market competitiveness.

Early research on modularity focused on its potential benefit within a competitive market. In an early, yet integral study of customer service measurement, Holcomb (1992) studied how organizations can become competitive by improving customers' quality perceptions. Holcomb observed that customer expectation was on the rise, and that value creation was not an improvement in customer service delivery. Instead, Holcomb found that improving customers' quality perceptions by, for example, improving length of order cycle, on-time deliveries, and completeness of shipments created more value than improvement in methods of customer service delivery in itself.

Similarly, according to Sharifi et al. (1999), responding to and taking advantage of changes through strategic use of manufacturing and managerial tools and methods were the key concepts of agile manufacturing. Although published in 1999, Sharifi and Zhang's study remains important because of its focus on competition within the manufacturing sector specifically. The introduction of agile manufacturing was an attempt to stay competitive in a business environment with fragmented mass market, where customer expectation was on the rise, and social pressure was high. Change then, as now, was one of the major characteristics of the new business era of the 21st century. Agile manufacturing was, and still is, a strategic approach to manufacturing in light of new and emerging business environments.

Until recently, much of the study of modularity was limited to the United States. For example, in their study of the use of modularity in Italian industry, Campagnolo et al. (2009) observed that before their research, all causal models of modularity were only available from the United States, despite the fact that modular organizational forms were a global phenomenon. Their work built on general systems modularity theory (Schelling & Steensma, 2001) and showed that industry specificities, labor intensity, as well as nation-specific factors, drives modularity.

Standardization and customization. In recent times, the task of satisfying the changing urge of customers, or customization, has become an important driver of modularity. Singh (2015) among others asserts that modularity afford organizations the flexibility to customize applications. However, Rahikka et al. (2011) described the challenge of many service firms as the ability to design an offering that is at once flexible and able to be fitted to the particular requirements of customers. Bask et al. (2011) observed that the increasing significance of services in the global economy and the growing variance of customer needs resulted in demands for efficient services tailored to customer needs. Customization is a competitive strategy that avail organizations the opportunity to create value for customers (Hong, Liao, Sturman, & Zhou, 2014). Despite the current need for more efficient and more flexible customization, standardization and customization has been fundamental to modularity since its inception.

While searching for standardization and efficiency within the building industry, Bemis (1933) introduced the concept of modularity and proposed the module concept—

understanding relationships between an entire system and its specific components—as an organizational theory for architects in the 1930s (Russell, 2012). The modular concept also became standard in the field of computer science in 1957 when IBM created the Standard Modular System (Russell, 2012). Under IBM's standard system, circuits had to have identical dimensions and components. For example, circuits would have identical elements like resistors, capacitors, and transistors to allow interchangeability. IBM took its concept of modularity and standardization from the 1940s United States Navy project, Tinkertoy, studying the techniques for printing circuits (Russell, 2012). The overarching idea in both cases is that modules, particular components of whole systems, feature standardized interfaces to allow for (re)integration within the overall system structure (Russell, 2012). In other words, standardized interfaces facilitate customization, a recombination of individual modules within the whole. This kind of customization and level of response characterizes two of the hallmarks of modularity: adaptability and flexibility.

The pace, with which firms respond to the needs of its customer, is indicative of flexibility, and this degree of flexibility is a criterion for excellence, noted Bask et al. (2010). Research, including that of Bask et al., asserted that organizations can attain higher levels of customer responsiveness through the practice of modularity because modularity allows for customization, a specific recombination of the parts within the whole. Recognizing and responding to customers is a primary reason for customization, and modularity is an important means to achieving customization (Bask et al., 2010). Bask et al. found that the degree of customization obtainable due to modularity vary based on service offering, service production, and production network. Despite the variations in the level of customization, it is important to emphasize that flexibility improves customer response and modularity enhances flexibility.

Regarding flexibility, Zhang (2011) noted how what he calls the *fuzzification* of organizational boundaries can help to stabilize organizations by making transaction boundaries—points of business, customer, and operational interaction—variable and flexible. These fuzzy, or blurry, boundaries help absorb or soften the effect of uncertainties from external sources, thereby stabilizing the organization and reducing internal costs (Zhang, 2011). Modularity affects organizational boundaries and also organizational processes, structure, and culture (Zhang, 2011).

Modular structures reflect the features of openness, flatness, and the capacity for self-organization; modular processes are ones of integration and independence, and a modular organizational culture in general is one that is more open and encourages trial and error (Zhang, 2011). Clearly, modular firms can benefit from agility and strategic flexibility—the effective and efficient use of standardization and customization—to gain competitive advantages. The competitive advantage of modular organizations is largely due also to focus on customers, optimization of internal resources and capabilities, and successful exploitation of external synergies from outside sources.

Advancements in technology. Along with market competition, technological advancement is one of the primary drivers of modularity. For example, Zhang (2011) credited technological advancement as the key behind value innovation because the idea of innovation involves the use of new technology in the production of unique products.

Zhang (2011) further elaborated by stating that employing new technologies also means the discovery of new production tools and new ways of assembling modular based components and technologies. The link between technological advancement and competitive advantage through the adoption of modularity in organizations results in lower cost, optimum resource utilization, and quick response to market changes (Zhang, 2011). In essence, the use of new technologies can help to enable the full realization of the advantages of modularization.

In addition, advancements in technology have made practicing modularity much easier. While investigating the affect of modularity-based manufacturing practices (MBMP) and manufacturing system integration (MSI) on manufacturing performance (MP), Liao et al. (2010) identified technological advancement as one of the most significant forces of change in the post-industrial manufacturing era. Liao et al. (2010) explored cost, quality, delivery, flexibility, and innovation as factors affecting MP. Among other things, the study found that better use of technologies has led to better use of modularity methods. For example, Liao et al. (2010) showed that effective use of advanced manufacturing technologies (AMT), flexible manufacturing systems (FMS), computer-integrated manufacturing systems (CIMS), and the MBMP improved MP.

Technological advancement drives modularity. The role of technology as a driver of modularity is clear in the study introducing the concept of modularity to business services. In their study, Pekkarinen et al. (2008) found that (a) change in technology and competition drove modular organizations, and (b) modularity allows the recombination of different inputs and the production of new cost efficient services more flexibly.

Pekkarinen and Ulkuniemi’s study (2008) showed how business service providers could make use of new technologies with a modularized platform approach to identify, develop, and deliver new services in a cost efficient and flexible manner.

Technological change also has implications for research hypotheses. For example, Furlan et al. (2013) showed how technological change affected the relationship between organizational modularity and product modularity in the air conditioning industry. This relationship between organizational modularity and product modularity rested on the across-firm mirroring hypothesis, wherein one facet of an organization mirrors another. Their study showed that this mirroring hypothesis did not hold up for technologically dynamic components and the accompanying supply relationships. This study further demonstrates the kinds of challenges technological change poses for manufacturing and service industries, as well as the potential of those industries employing modular designs to meet those challenges, or not.

Emulation and outcome. Demonstrable and positive empirical results from modularized organizations can make persuasive cases for others to emulate modular approaches. In an era when managers and policy makers are seeking any and every avenue to improve productivity and to stay competitive, approaches leading to positive results are prone to emulation. Sanchez (2008) has identified emulation as another significant driver of modularity. Other firms are likely to go modular in the product market if one firm can effectively demonstrates that modularizing the organization might yield competitive advantage (Sanchez, 2008). Ultimately, other firms will emulate credible, successful paths leading to business success. Emulation, of course, is linkable to outcome, another related and significant driver of modularity for businesses and organizations. In short, if business leaders in the product-manufacturing sector perceive that the architecture of modularity is capable of improving industry's product, process, and organization, modularity will become an industry-level phenomenon (Sanchez et al., 2013). Modularity will then become an outcome driven concept that other firms will feel compelled to adopt.

Cost advantage. The notion that practicing modularity within the manufacturing sector results in cost savings is common in the literature, but few have demonstrated these savings in empirical terms. Recent competition and customization have motivated manufacturers to institute modular organizations to manage supply chains. Using transaction cost analysis as a theoretical framework for the analysis, Cheng (2011) explored the driving force behind organizational modularity from the supply chain perspective. The central focus of Cheng's research was to identify the elements that drive modularity in the supply chain. Cheng (2011) found that diversified sources of supply and scale economies have a positive association with modular form organizations, and concluded that supply chain members can potentially save operational cost by implementing modularity at the organizational level. This work is important because it provided much needed empirical evidence on the upstream and downstream effect of organizational modularity.

The forgoing drivers of modularity create a reservoir of justifications for organizations to implement the concept of modularity. The exceptional circumstances or state of the organizations is in themselves triggers of modularity. The concept of modularity may be costly to implement; however, the convergence of business competition and a compelling case for outcome is sufficient reason to make the necessary investment.

Implementation of modularity methods. Beyond the justification question -is there any merit in investing in the concept of modularity, comes the *how to* question. This section reviews the modularity implementation approach according to Kremer and Gupta (2013). Kremer et al. (2013) reviewed and compared three modularity methods to determine the method, which generated the best modular design. The methods reviewed and compared were the function heuristic method, the behavioral-driven function-environment-structure (B-FES) modeling framework, and the decomposition approach. Their goal was to develop a framework for generating modularized designs that offer the highest ease of assembly and consider customer needs. Kremer et al. (2013) used the Oral B Dual Clean toothbrush and a generic bicycle design as the products for their study. After analyzing these three different modular designs using design for assembly (DfA) and design for variety (DfV) as variables, they concluded that the decomposition approach of Huang and Kusiak (1998) performed better than the function heuristic method or the B-FES modeling framework.

Contract manufacturing. The concept of contract manufacturing (CM) is important and it is at the forefront of this dissertation for various reasons: (a) The focal XYZ Company is a CM organization, and (b) the research question depends on the characteristics of the focal CM organization. This section is, therefore, vital to this work and deserves a thorough review. The following paragraphs are a review of the concept of CM.

CM is becoming increasingly more popular and prevalent in today's business environment wherein industries are constantly seeking to reduce costs and increase delivery quality. CM is a chain supply relationship wherein manufacturing firms outsource some of their manufacturing practices to an outside company through contractual arrangements (Han et al., 2012). CMOs, then, are also the original equipment manufacturers (OEM) that retain ownership of the products, and the contract manufacturer (CM) is the entity that is contracted and supplies skills and labor to manufacture the products (Han et al., 2012). Aerospace, defense, energy, pharmaceuticals, computer electronics, medical equipment, and automobile manufacturing are all industries that rely to some degree on CM (Han et al., 2012).

As it is with other business approaches, there are both benefits and drawbacks associated with CM. The prevalence of contracted, outsourcing arrangements may lead to a range of benefits to OEMs, including improved collaborative communication, cost reduction, increased value-added services, improved delivery quality, and asset reduction (Han et al., 2012). CM's additional benefits may include reducing time to market, easing capacity shortages, and enhancing production capacity (Han et al., 2012). Still, there are downsides to CM for OEMs. These downsides include lowered product quality, reduced innovation or investment in innovation, increased total cost of ownership, increased competition from powerful CMs, and lowered overall product quality (Han et al., 2012).

Han et al. (2012) observed that contrary to the perception that industry competition drives contract-manufacturing decisions, there is little empirical evidence concerning specific drivers of CM. In their study of the effect of industry competition on CM, Han et al. (2012) applied Porter's five forces model and value chain perspective to collect and empirically examine data on U.S. industries, collected from the U.S. Economic Census. The result showed that CM is associated positively with supplier industry competition, but industry competition and IT investment are moderating factors. Han et al.'s (2012) study is an important contribution to research on CM because it contributes toward providing empirical evidence on specific drivers of CM.

CMs can also transition to OEMs, becoming Own Brand Manufacturers (OBM) in their own right, and essentially coming to compete with their clients. Kuo (2011) offers an examination of such a transition using the computer company, Acer, as the subject of study. Kuo (2011) noted that the key to the company's transition was the ability to successfully reconfigure innovation capability and effectively manage the transition. It is also necessary that an organization have significant and sufficient dynamic capability, the capacity to purposefully create, extend, or modify its resource base (Kuo, 2011). In this case, Acer's dynamic capabilities primarily hinged on investments in its research and development (R & D) department and a reorganization of the company's focus from primarily manufacturing to service and innovation as well. In essence, Acer has become a competitive OBM through business expansion, technological innovation, and globalizing manufacturing. Furthermore, Kuo's study offers new and important contributions to research on CM and the innovation capacity reconfiguration of companies in developing countries, in this case East and South East Asia.

Summary and Conclusions

Modularity is a decades-old concept that has helped those in various areas of practice and disciplines of study better understand, approach, and manage complex systems. The underlying principle of modularity is that complex systems are manageable with ease if they can be broken down into components or modules able to act independently within the overall system architecture, as well as be de- and re-coupled strategically for specific purposes. Capacity utilization, efficiency, and profit margin are the variables used in this study and overhead cost and lead-time are the covariates.

Each variable for this research define specific manufacturing performance index and form the basis for analyzing modular and nonmodular units of the focal XYZ Company. CU measures the quantity of output of the manufacturing system. Efficiency is the ratio of time taken to complete a manufacturing activity to the planned time for that activity, and profit margin is the ratio of net profit to the sale price.

Comprehending the concept of modularity necessitated the explanation of related concepts and proximate concepts. Agility, flexibility, and CM are critical in explaining the subject as a whole in terms of triggers, justifications, and outcomes of implementing modularity. Modularity is beneficial to manufacturing firms because it allows for more overall operational flexibility, as well as gives modular firms considerable advantage in competitive markets and high technological environments. These benefits include increased customer service and responsiveness (customization), the ability to adapt to technological change effectively and successfully, and to refine internal mechanisms for value innovation.

Implementing the concept of modularity in an organization require allocation of resources. Therefore, decision makers seeking to modularize their organizations have to make a good business case. Drivers of modularity are rationalizations for investing in the concept of modularity. Three approaches for implementing the concept of modularity are (a) the function heuristic method, (b) the behavioral-driven function-environment-structure (B-FES) modeling framework, and (c) the decomposition approach Kremer et al. (2013).

Several researchers have noted that more study, especially of the empirical type, is still necessary on modularity as it relates to manufacturing. This study adds to the literature on modularity and manufacturing. Business environment has become more competitive, driving up the need for higher quality product at lower cost. Both of these needs have made CM quite popular, playing an important role in the economy. The concept of CM includes OEMs and non-OEMs. CMOs retain ownership of products. CMs enter contracts with other organizations to supply skill and labor to manufacture products. OEMs also become CMs by contracting to manufacture products. The subject of this research project, The XYZ Company, is a CM designed in a way that facilitates a potentially productive correlational study.

The XYZ Company consists of two major units: a modular department and nonmodular department. The research reviewed has shown that a modular organization offers specific benefits to firms and helps to set up this correlational study of the differences in the productivity of the modular and nonmodular departments of this CMO. Chapter 3 includes the methodology of this study.

Chapter 3: Research Method

I used a quasi-experimental research design in assessing the significance of modularizing CMOs. I planned to examine the effects of modularity within the scope of the XYZ Company. As outlined in Chapter 1, composability and decomposability characterize modularity as a flexibility tool. Composability refers to a decoupled modular unit's ability to recombine with one or more departments and create a larger entity, whereas decomposability refers to a modular unit's ability to decouple and become an independent entity. I posited that such modularity, along with the subsequent decomposability and composability, influenced an entity's capacity utilization, efficiency, and profit margin. This chapter delineates and outlines the research design and methodology, the pathway, in examining these possible outcomes, as well as the population and sampling procedure, data collection, analysis, threats to validity, and ethical considerations.

Research Design and Rationale

The study was a quantitative approach using archival data. Because I planned to examine statistical differences in a quantifiable set of variables, a quantitative approach was most appropriate (Howell, 2010). The particular focus of this research was to investigate the differences between modular and nonmodular departments within a CMO, on several measures of potential benefit. More specifically, I employed a quasi-experimental design to examine whether the modularized department had significantly different measures of utilization, profit, or efficiency than the nonmodularized department had.

This research included both dependent and independent variables. The dependent variables were CU, efficiency E_f, and profit margin PM. The key independent variable was whether the department was modular or nonmodular, and key covariates included OC and LT. The independent variables already existed based on the archival data categorization obtainable from the XYZ Company.

I considered other research methods for the study before concluding that a quantitative quasi-experimental design was most appropriate. For example, a mixed-methods approach is applicable only when the researcher plans to conduct both the initial exploration of factors that may be relevant to the modularization of a CMO, as well as the subsequent measurement of these factors in specific quantifiable ways (Urdan, 2010). A mixed-methods approach requires a qualitative analysis of these factors to determine a subsequent measure of the discovered factors. These measures of the factors then become inputs for the quantitative analysis (Howell, 2010). In this instance, I determined the affected factors and made plans to use quantitative designs to determine empirically valid findings.

The presence of established quantifiable outcomes associated with the modularization of CMOs is the main reason that a qualitative study is inappropriate (Urdan, 2010). In addition, I was not interested in rich subjective results regarding employee perceptions or lived experiences. Thus, the qualitative approach was not suitable for the current research.

The quantitative approach was the most appropriate approach for this research. Within the scope of quantitative research, I employed a quasi-experimental design employed for this study because it was not possible to randomly assign measures to one group, or another for the experiment, which would have been be by department type (modular department versus nonmodular department). In an ideal experimental study (i.e., a study in which the effect of a manipulated independent variable is examined through its affect on certain outcomes), the researcher is required to randomly assign departments to employ either modular or nonmodular paradigms. True experimental research uses this random assignment to contribute to equal variability between the groups in question (Pallant 2010). However, within the current research, this was not a possibility because I did not have this level of authority; the measurement level units were preassigned to the modular and nonmodular departments of the XYZ Company. The preassignment factor eliminated the foremost requirement of a purely experimental study, which states that observations can be randomly gathered or manipulated from a *control* or *treatment* group (Tabachnick & Fidell, 2012).

In this research, the data already exists in one category or another—modular and nonmodular, nominal variables. This grouping is outside of my control. The hallmark of quasi-experimental research is the preassignment into categories (Howell, 2010). In this quasi-experimental study with quantitative approach, I applied a test of mean differences to the measurements of capacity utilization, efficiency, and profit margin; these are the three dependent variables.

Methodology

Quantitative research design is testing hypotheses framed at the beginning of the research process. A systematic approach is necessary as a guide to the entire process.

This section includes the process and procedure for executing this research. The following paragraphs explain population, type, and source of data, sampling procedure, operationalization of variables, and plan for data analyses.

Population

The population for this research was the number of complete job orders undertaken at the XYZ Company from 2008 to 2013, the target period. The XYZ Company, the focal CMO, has modular and nonmodular departments with approximately 14,989 complete job orders within the target period. I drew appropriate sample sizes from the population of 3,823 for the modular department, and the population of 11,166 for the nonmodular department. Analyses involved jobs completed by modular and nonmodular departments; as such, the level of measurement was each completed job. The archival data covered a period of 5 years beginning from 2008.

Both groups' data resulted from completed jobs categorized by department. In this way, I could determine whether the modular department or the nonmodular department completed a job. In addition, all information pertaining to the dependent variables were available through documentation of completed jobs, and my responsibility was to calculate the specific variables of interest using this archival data.

Sampling and Sampling Procedure

If the population about which research is dedicated is large and the process of collecting data is cost prohibitive, or could take an unreasonably long period to complete, then it is logical to collect data from a manageable part of that population. This part of a whole (the population) is a sample, and the process of choosing a sample population for the purpose of data collection for a research is the sampling procedure (Babbie, 2012; Babbie, 2015). This research followed a probability sampling procedure explained below.

The jobs undertaken by both modular and nonmodular departments at the focal CMO were the source of data for this research. G*Power 3.1.7 was used to assess the required sample size that is necessary for finding statistical significance. Figure 3 shows G*Power calculation for ANCOVA sample size. Using the generally accepted power of .80 and assuming that there would be at least a medium sized difference between the two groups, the required sample size in order to find significance for an ANCOVA with 95% confidence level, two groups, and two covariates was 128 individual jobs (Cohen, 2013; Faul, Erdfelder, Buchner, & Lang, 2013).

There were no findings from prior research suggesting a statistical size of difference between the scenarios for my analysis. However, a medium effect size (f = 0.25) was chosen as a matter of practicality and as a business decision. For example, a small effect size of .10, needed to observe small change requires large samples size (n = 787). Drawing on my experience of the business, a small change will have an insignificant effect on the business and does not justify the cost of collecting an enormous data. A large effect size of.30 resulted in small sample size (n = 90); this may be insensitive to statistical size difference that could be harmful to the business. Figure 3 is a plot of the medium effect size of 0.25 using G*Power software. The medium effect size was chosen to avoid the expectation of extremes, such as an excessively large or small effect size (Tabachnick & Fidell, 2012). However, I will assume a large effect size for analysis if the variance is small. Large effect size requires a smaller set of samples;

therefore, making this change should not impede the process. A power of .80 was chosen as the desired power, as this is the generally accepted goal (Cohen, 1988).

The numerator degrees of freedom (numerator *df*) for this ANCOVA is 1. Numerator *df* is the number of factor levels (*k*) minus 1(*k*-1). Each scenario in Table 1 contains a dichotomous variable— a single independent FACTOR at 2 LEVELS. For this analysis, Modular = {Y, N}; where Modular is the independent factor, and Y, N count as two levels. Thus, the numerator *df* = (*k*-1) or 2-1 = 1. Given that all three scenarios have one dichotomous variable, then all have numerator *df* = 1; hence it is the same sample for all 3. An alpha of .05 was used to determine significance.

I collected information on each of the dependent variables from an equal number of modular and nonmodular department jobs; resulting in 131 jobs from modular department, and 131 jobs from nonmodular department. The process of sample job selection was random within the target population. Data pertaining to the outcomes were obtained from each job and customer until the sample size requirement was complete, or all available jobs' data was complete. The XYZ Company agreed to disclose information regarding the quantities necessary for calculating the dependent variables, work center details, sale prices and costs of jobs, for discrete part types, and the total number of discrete part types through archival sources.

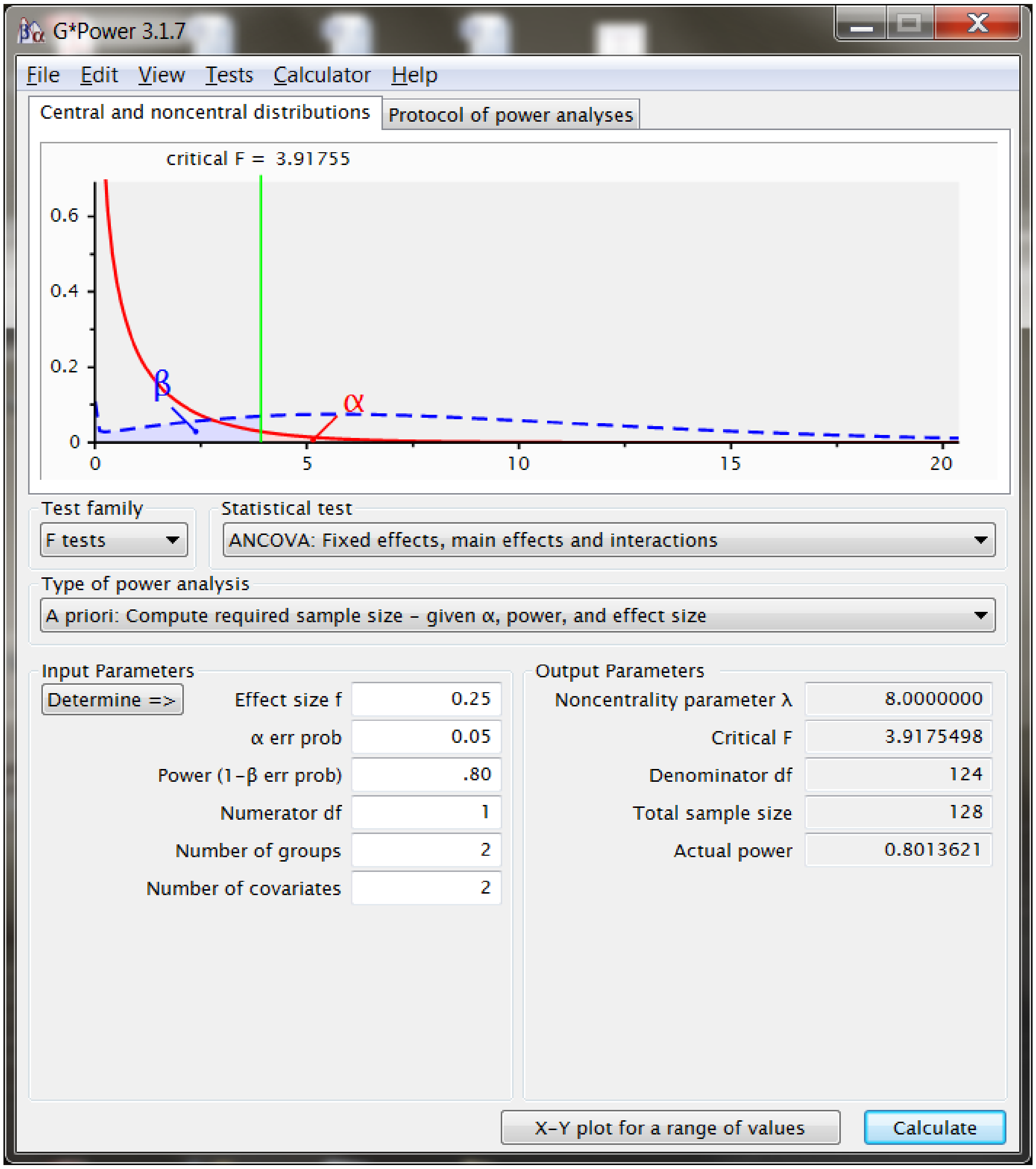

Figure 3. G*Power calculation for ANCOVA sample size.

Instrumentation and Materials

Data source (archival). Archival data from the XYZ Company was the main source of data for this research. The collection of information regarding capacity utilization, efficiency, and profit margin allowed for a comparison of these scale level measurements between modular and nonmodular departments. To collect these, I examined records of work order packets and job quotes covering a period of 5 years beginning from 2008. Using data from these sources, I calculated each variable of interest using the formulas described in the next section.

Operationalization of Variables

This section operationalizes the variables used for this research. I (a) identified the variables, (b) defined the variables, and (c) explained how to measure the variables. The dependent variables for this research are capacity utilization, efficiency, and profit margin. The covariates are OC and LT. Subsequent paragraphs contain the definition and explanation of the planned measurement of each variable.

Capacity utilization. Capacity utilization **(**CU) is calculated as the ratio of the actual parts that a machine produces to the number of parts that the machine is capable of producing per unit of time. This variable is a continuous level, and described as a percentage.

$$Capacity\ utilization\,(CU) = \frac{n}{N} * 100 \text{ - } (1),$$

where N = the number of parts that the machine is capable of producing per hour (a machine-rated capacity) and where n = the number of parts produced per hour. The number of parts actually produced per hour was available from records of work

Efficiency (E_f). The ratio of the amount of time actually taken to complete a manufacturing activity to the time an activity is planned to take. This variable is continuous and describes the efficiency as a percentage.

$$Efficiency(E_f) = \frac{T_a}{T_p} * 100 \text{ - } (2)$$

T_a = Actual Time

T_p = Planned Time

The data were derived from the work packet. The work packet contains manufacturing activities with planned times and a production log of actual times of completion. Planned times vary according to machine center and the production activity.

Overhead cost. Overhead cost (OC) is the cost of direct labor plus factory overhead (Kren, 2014). OC was used as a control measure and it was taken directly from the data source, and does not require calculation.

Lead-time. Lead-time (LT) is the time from the order entry to the time that the order was closed (Sjøberg, Johnsen, & Solberg, 2012). LT was taken directly from the data source, and does not require calculation; it is a control measure.

Profit margin. Profit margin (PM) is ratio of net profit to sale price, where net profit is the price of a job's sale price minus the cost of the job. This is also a continuous level variable, and describes the profit margin as a percentage. The data for calculating profit margin for a job was obtained from job quotes and the corresponding work packet.

$$Profit\ margin\,(PM) = \frac{Net\ Profit}{Sale\ Price} * 100 \text{ - (3),}$$

Where Net Profit = Job sale price - Job cost

A computer program at the XYZ Company analyzed completed jobs for profit or loss. Manual calculation of PM is possible by using data from job quotes and finished work packets. For example, a job quote contains cost of raw materials, each production step with associated cost per labor-hour, and the sale price, and the work packet contains actual time taken to complete each manufacturing activity. Actual cost consists in raw material cost and the labor-hour. The labor-hour cost varies according to the machine center and includes some overhead cost. Actual cost and profit margin can be calculated using data from work packets.

Data Analysis Plan

I screened the data for accuracy, missing data, and outliers or extreme cases. Then, I performed descriptive statistics and frequency distributions because they are appropriate tools to (a) determine that responses are within possible range of values, and (b) that the data is not distorted by outliers.

Descriptive statistics. I used the Statistical Package for Social Sciences (SPSS) software for Windows for all data analyses. I performed descriptive statistics to describe the sample demographics and the research variables used in the analyses. I calculated frequencies and percentages for nominal level data of interest for department type (modular versus nonmodular). A nominal variable is not continuous, but instead indicates categories. Nominal levels are merely labels without mathematical or rank order connotation. The application of nominal variable is available in the study by Dupper, Rocha, Jackson, and Lodato (2014). I calculated means and standard deviations for continuous level data of interest, namely capacity utilization, efficiency, lead-time, overhead cost, and profit margin (Howell, 2010). These data described the sample as a whole (i.e., for the total number of jobs for which data exists), and without any inferential analyses. As such, this data were useful here only in a descriptive sense. I conducted analyses on these variables in the subsequent sections of Chapter 4.

I tested the presence of outliers by examining the standardized residuals. Standardized residuals represent the number of standard deviations a measurement falls from the mean, and is calculable for each continuous level score. I examined cases for values that fall above 3.29 and values that fall below -3.29, indicating outliers (Tabachnick & Fidell, 2012). I also removed cases with large amounts of nonrandom missing data from the sample.

Research Question

What might be the value of implementing organizational modularity?

Assessing the research question involved the construction of three hypotheses that focused on the three potential benefits anticipated through the research. The hypotheses are:

H_{o1}: There is no significant difference in capacity utilization between the modular and nonmodular departments when controlling for differences based on overhead cost and lead-time.

H_{a1}: There is a significant difference in capacity utilization between the modular and nonmodular departments when controlling for differences based on overhead cost and lead-time.

H_{o2}: There is no significant difference in efficiency between modular and nonmodular departments when controlling for differences based on overhead cost and lead-time.

H_{a2}: There is a significant difference in efficiency between modular and nonmodular departments when controlling for differences based on overhead cost and lead-time.

H_{o3}: There is no significant difference in profit margin between modular and nonmodular departments when controlling for differences based on overhead cost and lead-time.

H_{a3}: There is a significant difference in profit margin between modular and nonmodular departments when controlling for differences based on OC and LT.

To assess the research questions; I used three *analysis of covariance* (ANCOVA). The ANCOVA was the appropriate analysis to compare differences that come from the same population when the dependent variable is scale level and the independent, or grouping, variable is dichotomous (Leech, Barrett, & Morgan, 2012).

Table 1 includes a summary of the variables and analyses used for each hypothesis test.

Table 1

Summary of Each Hypothesis Test

Hypothesis	Dependent variables	Independent variables	Control variables
1	Capacity utilization – continuous	Modular (Y/N) – categorical, dichotomous	Overhead cost– continuous Lead time – continuous
2	Efficiency - continuous	Modular (Y/N) – categorical, dichotomous	Overhead cost– continuous Lead time – continuous
3	Profit margin - continuous	Modular (Y/N) – categorical, dichotomous	Overhead cost– continuous Lead time – continuous

For each analysis, the independent (grouping) variable was the status of the department of job completion (modular versus nonmodular). The independent variable is a nominal level variable with two groups (i.e., dichotomous). The dependent variable for Hypothesis 1 is CU, E_f for Hypothesis 2 and PM for Hypothesis 3. Data for all three dependent variables are continuous. The two covariates, manufacturing overhead cost and lead-time, are continuous in nature as well and are thus appropriate to be included in the ANCOVA as covariates. Due to the two types of data to be assessed—continuous for the dependent variables, and ordinal for the independent variable—and the comparative nature of the research, this test of mean differences is the most appropriate analysis.

Table 1 includes a summary of the variables and analyses used for each hypothesis test.

Before analysis, I assessed the assumptions of the ANCOVA technique. ANCOVA calculates outcomes based on the assumption that the dependent variable is a normal distribution, and that the amount of variance between the two groups in question is nearly equal. These assumptions are the assumption of normality and homogeneity of variance, respectively. I assessed normality for each dependent variable using a one-sample Kolmogorov Smirnov (KS) tests for each. The *F* statistic is quite robust to minor violations of this assumption when the sample size is sufficiently large. Violations of this assumption within a sample of 30 or more have little effect on the results' validity (Stevens, 2009). Levene's test was performed to assess the homogeneity of variance; if the variance between the two groups was not found to be statistically similar, the statistics was interpreted using outcomes that do not assume equal variances.

ANCOVA procedures. Each ANCOVA analysis was conducted in SPSS version 22 for Windows; Green and Salkind (2010) outlines a step-by-step process. These analyses used the same data set to analyze differences in each of the dependent variable scales based on department status. In order to do this, several steps were be taken both before and after calculations. First, I assessed data to determine that data levels are appropriate. The independent variable must be categorical, and the dependent variables and covariates must be continuous. I listed the data for each of these variables in each column following appropriate variable labels, matched to each observation (i.e., job). Thus, each observation had a variable for modularity, which were coded as 0 if they are in the nonmodular group, and 1 if they are in the modular group. I represent covariates in two additional columns, where each row represented a particular job's overhead cost or lead-time. Finally, the dependent variables for each observation were held in the final four columns and were scale level numbers representative of each outcome. Once these data requirements were complete, analysis continued using the Analyze function in SPSS.

I selected the general linear model family of tests, and the univariate subfamily from this menu. This led to the specification pane for univariate analysis of variance, and allowed the entry of covariates into the model. Next, the dependent variable was identified by placement in the *dependent variable* box. This was repeated for each ANCOVA, or for each analysis. The grouping variable was then specified by placement in the "Fixed factor" box, which specifies independent variables in the model. Both overhead and lead-time were specified as covariates by placement in the "Covariates" box.

The model was *Full Factorial* and using the *Options* menu, I selected the specific statistical outcomes for the analysis. The analysis was prompted to display the comparison of main effects. To accurately interpret the ANCOVA, the group means and estimates of effect size must be selected as outcomes. This *Options* window also provided the option to conduct Levene's test, which was selected and used to assess the homogeneity of variance.

Outcomes for each variable may be interpreted using the F statistic and corresponding p value, which depend on the degrees of freedom. Rejection of the null hypothesis depended on the p value for the main effect (i.e., the independent variable), where a $p < .05$ indicated a significant difference between groups. At this stage, covariates may also be interpreted to indicate whether they had a significant effect on the dependent variable pertinent to each model. If there was a significant difference in a dependent variable based on grouping into a modular versus nonmodular, mean differences were examined to determine which group had a higher or lower average. Estimates of effect size was also examined using the partial eta squared outcomes; the resulting effect size for the grouping variable was an explanation of the statistical size of difference between groups while controlling for both of the covariates.

If the outcome suggests a violation of the assumptions of homogenous slopes, simple main effect models would be considered using a separate sample for multiple levels of the covariates. The covariates would be divided into three levels, representing low, medium, and high covariate level group. I determine the levels by taking (a) one standard deviation below the mean, (b) mean, and (c) one standard deviation the mean (Green & Salkind, 2010). This results in three analyses to examine either covariate, for a total of six analyses (i.e., three for low, medium, or high overhead cost, and three for low, medium, or high lead time). However, due to sample size limitations, this may not be the appropriate course of action. If participant numbers within any covariate level group result in insufficiently sized subsamples, the analysis may no longer be valid.

Strengths. The strengths of the data collection method are that it allowed a greater number of responses than is usual in quantitative studies. This study design enabled the examination and description of a sample of many jobs completed by the XYZ Company. Each job had its own different, specific data.

Sampling a large database of jobs provided a great number of responses, buoying the analysis process (Babbie, 2012) and significantly diminishing data collection time. In addition, the strength of the study was the flexibility of the analysis method, allowing a large number of questions asked on a given topic without the deployment of a new data collection instrument. This aided in the analysis of the independent variables and dependent variables should additional data require collection (Babbie, 2012).

Threats to Validity

Using archival data allowed the researcher to examine existing data and address research questions to bring forth new content or research outcomes. However, there are limitations to using archival data. Investigating issues that may occur might be an issue in archival data analysis because of the difficulty in finding pertinent data (Colorado State University, 2011). Additionally, variables in the data set could be controlled or altered without the researcher's knowledge. Another limitation of using archival data is that with large data files it is difficult to ensure that statistical software packages did not influence validity of the research (Colorado State University, 2011). Small sample sizes, along with biases based on nonrandom grouping into department types may also be an issue in regards to generalization or external validity. The passage of time may bring external changes, thereby, affecting comparative data validity.

Internal Validity

In order to attain validity, researchers must demonstrate causal inferences. Such causal inferences can occur when causes precede effects, when cause and effect relate in some way to each other, and when no plausible alternative explanation for the effect exists. Thus, key threats to internal validity can happen if temporal sequence of cause and effect are confused, or if there are alternative causes not accounted for, and also if there is selection bias (either intentional or inadvertent) in determining the sample.

In the case of this study, the key threat to internal validity was selection bias of the archival data; sample jobs already exist in modular and nonmodular categories. Whereas, this was an unavoidable limitation to quasi-experimental research, selecting sample jobs at random from each category ameliorates this threat. Another potential issue may arise in the validity of the results where data does not follow a normal (bell curve) distribution. However, I gathered data from over 30 jobs to counteract any potential nonnormal distributions. I also gathered data for the manufacturing overhead cost and lead time to be used as statistical controls and pare out these effects that that significant findings can be attributed to grouping in a modular versus nonmodular setting only.

Error from data entry may affect the shape of the distribution. The XYZ Company has a continuous improvement (CI) program, which requires the review of completed jobs. There is evidence of data entry error including wrong production quantity, not scanning out of a job when it is complete, and use of wrong code. For example, an operator scans production code instead of the machine down time code. The XYZ Company retrains operators to minimize data entry errors. However, I considered these factors when constructing the analyses and used a nonparametric statistical approach to remedy this threat where applicable.

External Validity

External validity is a measure of how well the results of a study are generalizable to the complete population or to a larger population. A small available sample size may cause an issue in regards to generalization when using archival data. In the case of this study, the first generalization was from the sample to the total population of all companies with modular and nonmodular departments. Key threats to external validity include attributes of the sample that contribute bias to the measured results, situational specifics of the study data collected, or effects that result from the use of specific settings, or a specific researcher. Thus, I took special caution in interpreting the results of this study, and did not assume that these results extrapolate to the entirety of the population of such organizations.

Ethical Considerations

Ethical principles are important in the implementation of this study. In planning the research, results were not misleading; the study was ethically acceptable, and participants protected. I kept all data on a password-protected computer with restricted access. The retention of data is 5 years; at the close of this period, the data will be permanently deleted. There were no financial incentives offering to any participant. Data were not falsified or fabricated. Appropriate citations were written for research conducted by other professionals. An institution undertook no part of this research, and there was no involvement of federal funding at any level. Thus, it was not required to meet corresponding guidelines.

The participation of individuals was not applicable in this study because I used archival data; thus, it reduced the risk of participants' identification and the need for individualized informed consent. I used archival data that has been previously collected and available to me upon request. There were no forms of deception in the completion of this study because of the nature of the research. There were services rendered by a psychologist, and there were no use of animals, both of which would otherwise require specialized research procedures.

Summary

This chapter included a detailed explanation of the procedures for this proposed research. These procedures outlined in depth to detail include the research design, methodology, data collection procedures, and finally the action plan regarding data analysis. I addressed issues of ethics and validity with consideration to potential methods that may remedy the difficulties or harms. I adhere strictly to these procedures in gathering and analyzing data in order to be effective and efficient in addressing the value of modularization in CMOs. Chapter 4 includes data collection, data analysis, and results of the study.

Chapter 4: Results

The purpose of this quantitative quasi-experimental study was to assess the significance of applying the concept of OM in CMOs. The approach was to conduct statistical tests of significance of three metrics: CU, PM, and E_f between the modular and nonmodular departments, while controlling for differences based on two covariates: OC and LT. The data for this study were archival data obtained from the XYZ Company. The data analyses were designed to respond to the research question: What might be the value of implementing OM?

Various disciplines have long applied the concept of modularity including organizations; however, empirical data to substantiate the positive attributes associated with modularity is lacking. The knowledge gap regarding the significance of modularizing CMOs is a result of the scant studies on modularity and specific CMOs. The absence of empirically-based data leaves decision makers in CMOs without the needed decision-making tool. The results of this study provide that tool; this tool may give policymakers in CMOs some understanding the implications of implementing the concept of OM.

This chapter is a presentation of results of this study as obtained from analyses directed at responding to the research question and the following hypotheses:

Research Question: What might be the value of implementing OM?

H_{o1}: There is no significant difference in CU between the modular and nonmodular departments when controlling for differences based on OC and LT.

H_{a1}: There is a significant difference in CU between the modular and nonmodular departments when controlling for differences based on OC and LT.

H_{o2}: There is no significant difference in E_f between modular and nonmodular departments when controlling for differences based on OC and LT.

H_{a2}: There is a significant difference in E_f between modular and nonmodular departments when controlling for differences based on OC and LT.

H_{o3}: There is no significant difference in PM between modular and nonmodular departments when controlling for differences based on OC and LT.

H_{a3}: There is a significant difference in PM between modular and nonmodular departments when controlling for differences based on OC and LT.

Data Collection

The institutional review board (IRB) approved data collection for this study on May 5, 2015; the IRB approval number is 05-05-15-0074023. Archival data collected covered a period of 5 years, 2008 to 2013. The data from the XYZ Company on production activities contained direct information and provided components that allowed for the calculation of CU, E_f, PM, OC, and LT. I prepared the data by first calculating the components of the variables prior to entry into the statistical analysis software.

Data Treatment

A total of 262 data on unique jobs were collected from modular and nonmodular departments. From this raw data, the measures of CU, E_f, and PM were calculated using the following formulas:

$$Capacity\ utilization\,(CU) = \frac{n}{N} * 100 \text{ - } (1)$$

$$Efficiency(E_f) = \frac{T_a}{T_p} * 100 \text{ - } (2)$$

$$Profit\ margin\,(PM) = \frac{Net\ Profit}{Sale\ Price} * 100 \text{ - } (3)$$

These equations already exist in detail in Chapter 3. LT derived from job open and close dates; OC was a direct value from the raw data. Once a continuous measure of calculation was reached for each of these variables, univariate outliers were examined by calculating standardized residuals. These standardized residuals are a measurement of the number of outliers any job lies from the average for that variable. According to Tabachnick and Fidell (2012), any observation that lies more than 3.29 standard deviations above or below the mean is an outlier and should be removed so that it does not distort the data. Following these guidelines, a total of 12 jobs were not considered for the statistical analyses. CU depleted by one job for an outlier. Efficiency lost three jobs for outliers. OC depleted by four jobs for outliers. LT lost two jobs for outliers, and two outlier jobs removed from profit margin. After this preliminary data cleaning, a total of 250 jobs remained in the data set and were deemed useful in conducting valid analyses.

Descriptive Statistics

Of the final 250 jobs in the final data set, there were nearly equal jobs from modular (127, 51%) and nonmodular (123, 49%) departments. The average CU was found to be 113.52 (*SD* = 454.60) in this full sample. The E_f measurement ranged from 0.65 to 4,950, with an average of 283.13 (*SD* = 520.89). LT measured in days and ranged from three to 221, with an average of 46.41 (*SD* = 38.19). OC centered on a mean of $1,597.29 (*SD* = $1,727.45) in the present sample. PM ranged from -$97.22 to $225.39, with an average of $38.77 (*SD* = $39.38) in the given sample. Table 2 is a presentation of these sample-wide measurements as an overall description.

Table 2

Means and Standard Deviations for Overall Sample Variables

Variable	Min.	Max.	*M*	*SD*
Capacity utilization	2.02	7,150	113.52	454.60
Efficiency	0.65	4,950	283.13	520.89
Lead time	3	221	46.41	38.19
Overhead cost	$19.17	$7,986.91	$1,597.29	$1,727.45
Profit margin	-$97.22	$225.39	$38.77	$39.38

Study Results

Three analyses were conducted in the present study and each focused on the examination of a different measure of value, and how these measures differ between the modular and nonmodular departments. The conduct of each of these analyses aimed to examine any such differences while also controlling possible differences due from the interaction between the variables and the covariates—OC or LT, respectively. The following section contains details of these findings and visually assessed in Figure 1.

Detailed Analyses

The following analyses partained to the research question, what might be the value to implementing organizational modularity? To adequately explore this research question, three hypotheses were tested using a series of ANCOVA analyses. The following are the hypotheses and each accompanying detailed analysis.

Hypothesis 1

H_{o1}: There is no significant difference in CU between the modular and nonmodular departments when controlling for differences based on OC and LT.

H_{a1}: There is a significant difference in CU between the modular and nonmodular departments when controlling for differences based on OC and LT.

To assess Hypothesis 1, an ANCOVA was conducted to evaluate differences in the CU of modular and nonmodular departments while controlling for differences based on OC and LT. A total of 247 jobs had all the appropriate data for this analysis and included in this calculation. Prior to analysis, the assumptions of the ANCOVA model were tested. First, the ANCOVA assumes a normally distributed dependent variable. This assumption was tested using a one sample Kolmogorov Smirnov (KS) test. Results of this test indicated that the capacity utilization was significantly different from a normal distribution ($p < .001$); this assumption was not satisfied. However, Stevens (2009) states that violations of this assumption have a relatively small effect on the outcome when the sample size exceeds an *n* of 30. The total sample size deemed for this study exceeds 700% of the minimum required. Second, the ANCOVA assumes equality of variance. The assumption of equality of variance was assessed using Levene's test. Results of this assessment indicated that the modular and nonmodular groups had similar variances and were thus statistically comparable (F [1, 245] = 3.48, $p = .063$).

Results of the ANCOVA indicated a significant difference in capacity utilization between jobs in the modular and nonmodular departments after controlling for differences based on overhead cost or lead time (F [1, 243] = 5.14, $p = .024$, partial η^2 =

.02). These findings correspond with a statistically small difference, based on Cohen's (1988) guidelines for effect size interpretation. The nonmodular department had a mean capacity utilization of 29.70 (*SE* = 46.86), and the modular department had a mean capacity utilization of 202.23 (*SE* = 48.58) upon controlling for differences based on the two covariates—overhead cost and lead time. Thus, the modular department was found to have significantly higher capacity utilization than the nonmodular department. Accordingly, the null hypothesis was rejected in preference to the alternative. In addition, neither of the covariates were found to be significantly related to capacity utilization. Table 3 is a presentation of the results of the ANCOVA.

Table 3

Results of ANCOVA for Capacity Utilization Between Modular and Nonmodular Departments

Factor	SS	MS	$F(1, 243)$	p	Partial η^2
Modular status	1,050,656.54	1,050,565.54	5.14	.024	.02
Lead time	30,753.31	13,753.31	0.15	.699	.00
Overhead cost	465,950.15	465,950.15	2.28	.132	.01
Error	49,698,515.73	204,520.64	-	-	-

Hypothesis 2

H_{o2}: There is no significant difference in E_f between modular and nonmodular departments when controlling for differences based on OC and LT.

H_{a2}: There is a significant difference in E_f between modular and nonmodular departments when controlling for differences based on OC and LT.

To assess Hypothesis 2, an ANCOVA was conducted to assess differences in the efficiency of modular and nonmodular departments while controlling for differences based on overhead costs and lead-time. A total of 247 jobs had all the appropriate data for this analysis and used for this calculation. Before analysis, the assumptions of the ANCOVA model were assessed. The assumption of normality was tested using a one sample KS test. Results of this test indicated that the efficiency distribution was significantly different from a normal distribution ($p < .001$), and this assumption failed. As above, the violation was not severe enough to warrant concern. Results of Levene's test indicated that the modular and nonmodular groups had dissimilar variances (F [1, 245] = 19.25, $p < .001$). Accounting for this violation required the interpretation of significance with a much smaller alpha value. The interpretation of significance used a more stringent alpha of .025 (.05/2). Stevens (2009) suggest that violations of this assumption may result in the corresponding ANOVA being too liberal, or rejecting the null hypothesis too often. This situation increases the chance of Type I error. I used a more stringent alpha of .025 (α =.025) in the interpretation of significance because it failed the Lavene's test of equal variance. The use of a modified alpha of .025 to interpret significance is an adequate countermeasure (Stevens, 2009).

Results of the ANCOVA indicated a significant difference in efficiency between jobs in the modular and nonmodular departments to the modified alpha of .025, and after controlling for differences based on overhead cost or lead time (F [1, 243] = 8.65, p = .004, partial $\eta^2 = .03$). These findings correspond with a statistically small difference, based on Cohen's (1988) guidelines for effect size interpretation. After controlling for differences based on the two covariates, nonmodular department tended to have an efficiency measure of 404.99 on average (SE = 52.49), while modular department tended to have an efficiency measure of 154.17 (*SE* = 54.42). Thus, nonmodular departments were found to have significantly higher efficiency than their modular counterparts. The null hypothesis is, therefore, rejected in favor of the alternative. Similar to the case for CU, neither overhead cost nor lead-time was found to be significantly related to efficiency. Table 4 is a presentation of the results of the ANCOVA.

Table 4

Results of ANCOVA for Efficiency Between Modular and Nonmodular Departments

Factor	SS	MS	$F(1, 243)$	p	Partial η^2
Modular status	2,220,421.14	2,220,421.14	8.65	.004	.03
Lead time	140,132.73	140,132.73	0.55	.461	.00
Overhead cost	62,660.071	62,660.071	0.24	.622	.00
Error	62,372,107.04	256,675.338	-	-	-

Hypothesis 3

H_{o3}: There is no significant difference in PM between modular and nonmodular departments when controlling for differences based on OC and LT.

H_{a3}: There is a significant difference in PM between modular and nonmodular departments when controlling for differences based on OC and LT.

To assess Hypothesis 3, an ANCOVA was conducted to assess differences in the profit margin of modular and nonmodular departments, while controlling for differences based on overhead costs and lead time. All 250 jobs had all the appropriate data for this analysis and were included in this calculation. Prior to analysis, the assumptions of the ANCOVA model were assessed. The assumption of normality was tested using a one sample KS test. Results of this test indicated that the profit margin distribution was significantly different from a normal distribution (p = .042), and this assumption was not met. However, Stevens (2009) stated that violations of this assumption have a relatively small effect on the outcome when the sample size exceeds an n of 30. The sample for this study well surpasses the required minimum of 30 samples stipulated by Stevens (2009). Results of the Levene's test indicated that the modular and nonmodular groups had similar variances, and were thus statistically comparable (F [1, 248] = 2.15, p = .144).

Results of the ANCOVA indicated a significant difference in PM between jobs in the modular and nonmodular departments after controlling for differences based on OC or LT (F [1, 246] = 49.90, p < .001, partial η^2 = .17). These findings correspond with a medium statistical difference, based on Cohen's (1988) guidelines for effect size interpretation. After controlling for differences based on the two covariates, nonmodular department tended to have a profit margin of 56.89 on average (SE = 3.24), while modular department tended to have a profit margin of 20.06 (SE = 3.31). Thus, nonmodular department were found to have significantly higher profit margins than their modular counterparts, and the null hypothesis rejected in favor of the alternative.

Overhead cost was found to be significantly related to the profit margin, though only to a small extent based on the partial η^2 of .05 (Cohen, 1988). By creating scatter plots, the relationship between overhead cost and profit margin was examined. This plot suggested that lower job overhead costs corresponded with higher profit margin, and can be viewed in Figure 4. By using this variable as a covariate in the ANCOVA model, this effect was parsed out so that differences based on profit margin could be examined independently. Table 5 is a presentation of the results of the ANCOVA. Figure 5 depicts these differences based on the estimated marginal means.

Table 5

Results of ANCOVA for Profit Margin Between Modular and Nonmodular Departments

Factor	SS	MS	$F(1, 246)$	P	Partial η^2
Modular status	49,230.922	49,230.922	49.90	< .001	.17
Lead time	2,509.62	2,509.62	2.54	.112	.01
Overhead cost	12,720.05	12,720.05	12.89	< .001	.05
Error	242,724.52	986.69	-	-	-

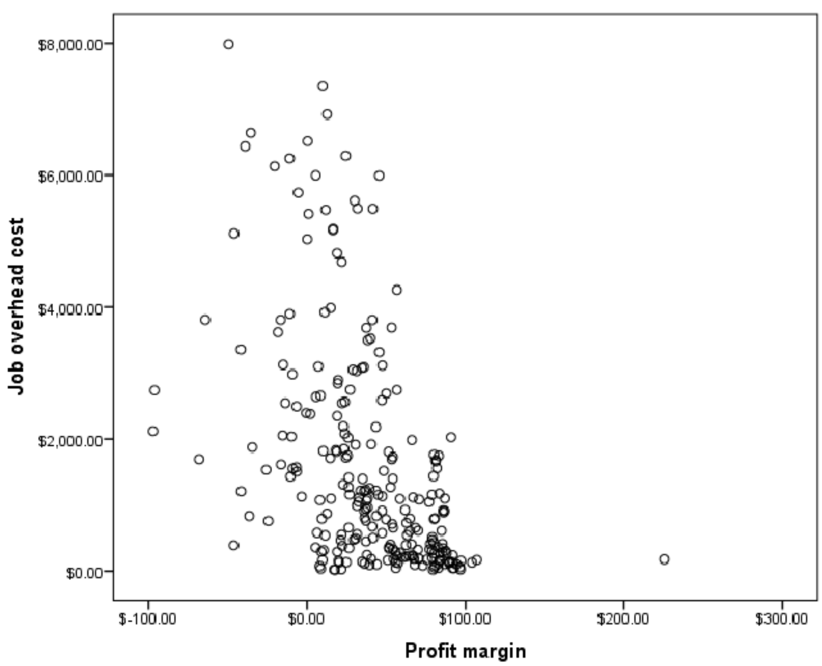

Figure 4. Scatterplot to assess the relationship between overhead cost and profit margin.

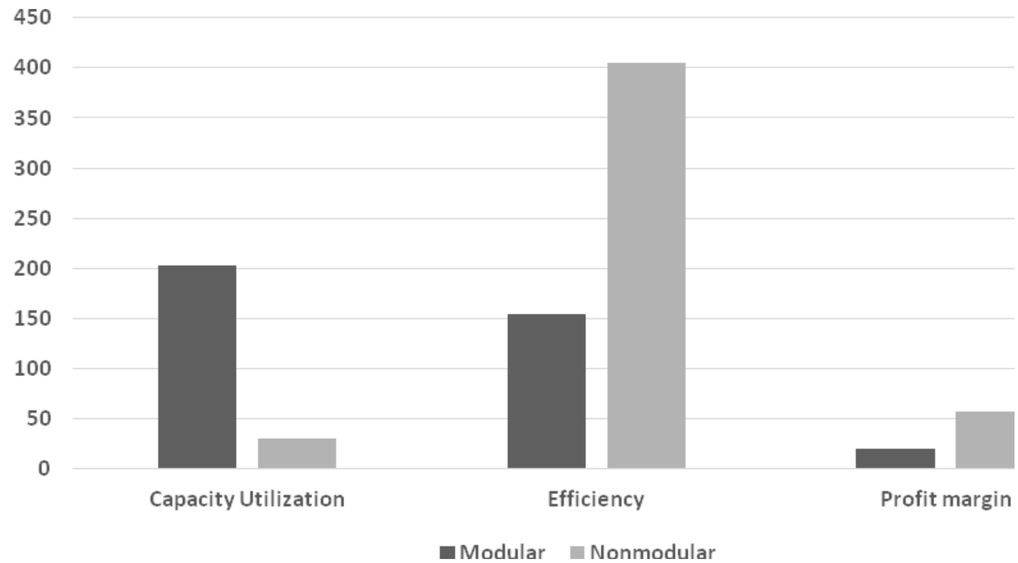

Figure 5. Marginal means for capacity utilization, efficiency, and profit margin between modular and nonmodular departments.

Summary

This chapter included a description of the sample and procedures for data cleaning, as well as a summary of the results. Following these procedural details is a summary of the results, with the findings interpreted without numerical data or tabulations. Following this summary is the listing of detailed analyses and the specific numerical outcomes. This section includes details of the assumption tests and a tabulation of each of the ANCOVA results. Chapter 5 includes additional detail on these results, and includes a discussion of the findings as they correspond with the prior literature. This chapter also includes suggestions for further research such that the issue of modularity may be better understood especially by policy makers in CMOs.

Chapter 5: Discussion, Conclusions, and Recommendations

This study was about assessing the significance in modularizing CMOs. The decision to modularize or not modularize an organization, partially or wholly, may well be the reason for the survival of the enterprise. Organizations may not apply a strategy uniformly across the board all the time (Bell, 2015). Still, empirical data on the assessment of any significance that may exist in modularizing CMOs are lacking. It seems that the absence of information has led to inadequate understanding of modularity principles on the part of policy and decision makers in the CM domain. The United States International Trade Commission (USITC) Publication 4125 (2010) indicated that the role of CMOs in the United States economy is on the rise. Cavazos (2011) stated that North American CMOs in the electronics sector alone earned projected revenues of more than $45 billion in 2011. According to GBI Research (2013), the global pharmaceutical CMO market grew at a CAGR by 10.7% from $21.2 billion in 2008 to $26 billion in 2010. GBI Research (2013) also forecast a revenue growth of $59.9 billion by 2018. I assessed the significance of modularizing CMOs using the XYZ Company as a case study.

Findings in the literature portray that organizations are driven to modularity practices for a plethora of reasons but, ultimately, companies are more motivated by changing business circumstances and technological innovation. The literature further expressed that modularity is a way to understand and approach the organization of complex systems. First introduced by Bemis in relation to architectural theory in the 1930s, modularity has helped those in various areas of practice and disciplines of study better manage complex systems. The underlying principle of modularity is that complex systems are manageable if broken down into components or modules able to act independently within the overall system architecture. Such modules could as well be decoupled and recoupled strategically for specific purposes. For the purpose of this study, the modules are the respective departments; the modular department is independent and could decouple and recoupled to the overall organization, the XYZ Company. One advantage of modularity, among others, is the flattening of the barrier to the industrial value chain, allowing for the entry of small firms (Liu, Wu, & Lai, 2015). Liu et al. further stated that these companies start small and gradually grow to disrupt the market as they acquire technologies.

Recent studies on OM suggest that the application of modularity principles leads to faster response to economic and competitive market change (Cheng, 2011; Ernst, 2005). Modularity provides for adaptability and flexibility (Cheng, 2011). The demand for standardization and customization is and the changing trend in the business environment that contributes to the pursuit of modularization (Rahikka et al., 2011). Other factors include advancements in technology, cost advantages, and the emulation based on concrete outcomes. It is a common notion, in the literature, that modularity is capable of improving industry's product, process, and organization despite sufficient empirical data (Sanchez et al., 2013). For example, Ridolfi and Giustolisi (2015) stated that the implementation of modularity to the analysis and the management of tasks simplify a process of what is otherwise a complex.

I employed a quasi-experimental design to assess if the modularized department had significantly different measures of CU, E_f, and PM than the nonmodularized department. The analyses are conducted using the ANCOVA statistics for each variable—CU, E_f, and PM while controlling for LT and OC. Discussion of findings, the study limitations, implications of social change, and recommendations for further study are addressed in this chapter.

Interpretation of Findings

A total of 250 unique jobs from modular and nonmodular departments were included on the study. Of the 250 jobs, there were nearly equal jobs from modular (127, 51%) and nonmodular (123, 49%) departments. One research question and three hypotheses were addressed in this study. The findings indicated a significant difference between modular and nonmodular departments for the variables used for this study—CU, E_f, and PM while controlling for two covariates—OC and LT. Based on these results; all three null hypotheses were rejected in favor of the alternative. However, neither the modular department nor the nonmodular department had consistent higher scores for CU, E_f or PM.

As expected, findings indicated significantly higher CU for the modular department than the nonmodular department. This result of differences in both departments was in line with the expectation. CU is a viable variable for measuring the effects of modularity on manufacturing performance (Morin & Stevens, 2005; Ragan, 1976; Wang et al., 2007). In a study focused on the service industry, Sun and Wong (2010) showed that CU is a useful variable in the study of productivity. The application of CU to CM yielded the expected outcome. This finding corroborates that of Cheng

(2011). Assessing the performance of modularity to manage supply chains, Cheng found that modularity positively affects CU.

A significant difference exists in E_f between modular and nonmodular departments. Whereas the difference between both modular and nonmodular was expected, the direction was counter to expectation. Higher marginal means of E_f in the nonmodular department is contrary to previous findings. Cheng (2011) associated higher level of E_f to a higher level of modularity in his study assessing the performance of modularity in the management of supply chains. The results of this study associate lower E_f with modularity when applied to specific CMO.

The last metric is the PM. A statistically significant higher marginal mean for PM is observed for the nonmodular department when compared to the modular department. Differences in PM between modular and nonmodular departments were well within expectation; however, the direction was not expected. Given the findings of Cheng (2011), associating modularity with profitability, a lower marginal means for PM in the modular department for this study is a surprise. This finding is also at variance with Danese et al. whose study of modularity's effect on new product development (NPD) time performance efficiency found that product modularity and integration practices increased efficiency.

The findings of this study manifest significant value in modularizing contract-manufacturing organizations. Three findings in this study are as follows. First, significant differences exist between modularized and nonmodularized CMOs for CU, E_f, and PM. Second, the type of service or industry may affect the differences observed in CU, E_f, and

PM. Third, modularization may not be a suitable option for all problems or organizations. The notion of incompatibility of modularity to all organizations or problems is the same held by Langlois (1999). Specifically, Langlois (1999) stated that a modular approach was not suitable in areas requiring highly specialized assets.

Research Question and Hypotheses

The research question for this study is, what might be the value of implementing organizational modularity? This study claimed that there were significant differences in CU, E_f, and PM, across the dichotomous modular and nonmodular departments while controlling for OC and LT. These hypotheses solely drove the analyses needed to answer the research question. As stated, signifcant differences exist across modular and nonmodualr departments.

Hypothesis 1: The investigation assessed significant difference in CU between the modular and nonmodular departments when controlling for differences based on OC and LT. The result indicates significant difference in CU between modular and nonmodular departments. The modular department shows a higher statistical significance. The result of this study is consistent with previous research findings. The higher statistical signifance of CU of the modular unit over the nonmodular unit seem to imply that modularity may be appropriate to resolving undercapacity utilization concerns. This study is CMO-specific, however, this conclusion may be generalized because there are several studies on non CMOs with the same findings. For example, Cheng (2011) found that modularity had a positive effect on modularity. The results of this study are an essential addition to the kowlegde base of OM because it is the first to focus on specific CMOs.

Hypothesis 2: The investigation assessed, if any, a significant difference in E_f between the modular and nonmodular departments when controlling for differences based on OC and LT. The nonmodular unit was found to have significantly higher E_f than the modular unit. As indicated earlier, this result was not expected because it is opposite to previous findings in the literature. Although other studies did not focus on CMOs specifically, they attributed higher E_f to modularity. For example, Cheng (2011) associated higher E_f with modularity in the study focusing on supply chain. Similarly, Danese et al. (2010) attributed higher performance efficiency to modularity in a study on new product development.

The difference in findings for this study may be due to the CM domain. Secondly, the focal CMO is partially modularized. A partially modularized organization maintains some characteristics of a nonmodular organization; these inherent residual traits may influence the overall conduct of the modular unit. This view is supported by the assertion of Langlois (1999) who concluded that modularity may not be the solution to all situations.

Hypothesis 3: The investigation was to assess significant differences in PM between the modular and nonmodular departments when controlling for differences based on OC and LT. The nonmodular department was found to have significantly higher PM than the modular department. A statistical significance is seen for PM and OC as shown in Figure 4. The effect of OC on PM was expected. The lower PM for the modular department was surprising based on persuasions from the literature. For example, Cheng (2011) associated higher PM to modularity.

As noted earlier, partially modularized organizations may exhibit characteristics of nonmodular organizations that are capable of exerting negative influences on performance. Data from the modular department had some unplanned activities that could potentially have negative effect on PM. *Unplanned activities* in manufacturing are process steps that were inadvertently omitted during planning but was undertaken to successfully complete a job. Unplanned activity could lead to misapplication of capacity cost (Snead et al., 2010). Snead et al. recommended a strategy for determining the causes of misapplied capacity costs in relation to OC.

Difference in CU, E_f, and PM across modular and nonmodular departments is a lesson that organizational leaders, particularly those in CMOs, ought to consider building upon. Empirical studies on modularity with respect to CMOs remain scant. This study bridges the gap in assessing the statistical significance in modularizing CMOs. The result of this study is a tool for policy makers in organizations when deciding if, why, and when to invest in the implementation of modularity. This study provides extensive review of the literature, the grounds for or against the implementation of modularity practices, and finally, the metrics for consideration based on the issues facing the organizations.

Limitations of the study

There are many limitations to this study. The raw data and method for deriving certain components for the variables and other factors contributed to the overall limitation of this study; consequently, conclusions are cautiously encouraged. The raw data contained data sets that are directly applicable to the analyses, but some components of the variables are derivatives of values within the raw data. The data screening process was a remediation for some data sets that seemed inconsistent.

Data sets required for the calculation of other components were incomplete for some particular jobs or not directly available from the raw data. For example, number of parts that the machine is capable of producing per hour (*N*), the component for measuring CU, was derived from the planned parts per hour data set. Therefore, *N* for a particular activity was the ratio of order quantity to the planned time. For jobs having multiple activities, I used the sum of planned time (T_p) from each activity to calculate the job's overall T_p and N respectively. Whereas the data screening process for this study was robust, few jobs were missing planned times.

The net income (for PM) is a direct raw data value. However, certain job data contained a revised value—adjusted margin. It was evident in the data set that the gross margin is the difference between total cost and total sales. However, I found that XYZ Company might revise gross margin down or up to get an adjusted margin. I used the adjusted margin for the analyses where both gross margin and adjusted margin coexisted in the raw data set.

Reliance on data from one source limits generalization of the findings from this study. The XYZ Company operates modular and nonmodular structure. This study used data from a single organization. Lastly, OM is not measured in this study. The measurement of OM would have provided the extent to which the modular department is modular. Results on the degree of modularity would have indicated the location level of modularity of the modular department on the modularity continuum. An established level of modularity may have also enabled true relationship between and CU, E_f, and PM respectively.

This current study contributes to the body of knowledge on OM particularly CMOs. During this work, I did an extensive review of existing scholarly research and to the best of my knowledge this is the only study that assessed the significance of modularizing CMOs. The findings of this research are justifications for future research.

Implications for Social Change

The purpose of this study was to provide policy and decision makers in CMOs an empirically based knowledge so that they can make correct decisions concerning the implementation of modularity practices. The decision of —when to or not to, wholly or partially, modularize an organization may well be the single decision behind a company's survival or demise. The results of this study are a contribution to the set of tools needed in reaching that decision; therefore, the results of this study may have enormous social change implications.

Indications from the recent literature are that modularity is good for organizations. Positive attributes associated with modularity include cost savings, product variety, flexibility, specialization, and customization (Bask et al., 2011; Bask et al., 2010; Gomes et al., 2010; Jose et al., 2005; Pekkarinen et al., 2008). However, Langlois (1999) warned that modularity is not a panacea for all situations and organizations. The literature lacks empirical data to support the case for or against modularizing CMOs. To the extent that the results of this study provided these tools to decision makers in CMOs, this study may have several implications for social change.

I reviewed the social change implications from two perspectives—the survivability or the demise of the organization and the cost of goods and services. The literature established that modular organizations possess, among others, the ability to respond quickly to—customers and—changes in the business environment. The result of this study also shows that there can be a remarkable difference between modular and nonmodular organizations. For this reason, decision and policy makers in CMOs must be cautious in the decision to or not modularize. For example, the XYZ Company's modular department tends to have better CU—approximately 500% better than the nonmodular department. At the same time, the modular department showed weakness in both E_f and PM. An estimated 2 million companies in the United States filed for bankruptcy during the 12 month periods ending March 31, 2014 and 2015 respectively (United States Courts, n.d). Of this number, approximately 70% will survive (LoPucki, 2015). This study results may lead to a reduction in bankruptcy filings.

An uneducated business decision may lead to loss of revenue, less competition and ultimately bankruptcy. The findings of Hagedorn (2015) on decreased revenue and Kao (2015) on the subject of competition are explicit on the danager that wrong business decision poses to orgarnizarons. Kao declared that competition bankrupts companies but a smart decision eventually revives the organization. Surviving organizations have the tendency to last long, employ more people, and keep employees employed for a longer period. The decision to, or not to, implement modularity in CMOs may hinge on the survival of the organization and getting it wrong may have a far reaching effect on the 45.3 million people already in poverty in the United States (DeNavas-Walt & Proctor, 2014).

This study result adds to the knowledge pool for policy makers in CMOs concerning the decision to expend resources to boost profit. Leaders in organizations would use available information to increase profitability (Assenza, Grazzini, Hommes, & Massaro, 2015) and could offer quality products at affordable prices. The social implication is that more people—are employed, have a better standard of living, have better health, and lifted out of poverty.

Recommendations for Action

The results of this study indicate that more research on the concept of modularity with respect to CMOs remain a necessity. The need for more studies is in alignment with previous scholars. For example, Schilling et al. (2001) called for the extension of the study of modularity to CMOs. Similarly, Liao et al. (2010) recommended the expansion of studies on modular perspectives to better understand the effect of modularity. Despite the growing importance of CMOs in the present global economy, studies on modularity with focus on CMOs are limited. Thus, decision and policy makers in CMOs may not have the necessary knowledge for making sound business decisions regarding the implementation of modularity.

The results of this study show that the practice of modularity in the focal CMO tends to favor CU. I found that CU improved over 500% in the modular department over the nonmodular department. This reflects the findings of Cheng (2011) who found that modularity had positive effect on CU when applied to supply chain.

Recent findings suggest a similar positive effect of modularity on organizations. For example, Liu et al. (2015) suggested that technological modularity facilitates the evolution of industrial value chain, which significantly lowers the threshold for local small firms' entry and promotes disruptive innovations. Shanzhai mobile phone companies start from low–end disruption, by accumulating technology and market knowledge through resource integration, could work their way up to eventually achieve independent innovation and their own brands, becoming major players in the market.

Michaud (2015) noted that modularity principles in manufacturing (easy to assemble modules) have driven up foreign direct investment for electronics-producing multinational enterprises (MNEs) while simultaneously boosting the economy of developing nations. For example, Brazil's Foxconn produces the iPads for Apple, and Microsoft and Sony also have assembly plants for the xbox360 and platystion3 respectively in Brazil (Michaud, 2015). Implementation of modularity to the analysis and the management of tasks is a simplification process of what is otherwise a complex endeavor (Ridolfi et al., 2015).

The results of significant differences in the CU, E_f, PM, between the modular and nonmodular units echo the literature regarding the rationale for implementing modularity. According to the literature, organizations are driven to the concept of modularity for reasons including market competition, standardization and customization, advancements in technology, emulation and outcome, and cost advantage. Whereas it seems that the existence of a business depends on the implementation of modularity, the lack of sufficient empirical data, such as this study provides, yields inadequate enlightenment of policy and decision makers in the CM sector.

Besides the call for more empirically-based studies, I recommend the following: (a) Inclusion of the concept of modularity in the masters of business administration (MBA) curriculum, (b) CMOs to sponsorship studies relevant to practical application of the concept of modularity, and (c) professional associations relevant to the business, the management, and the administration of CMOs to include the concept of modularity in their lecture series and award commensurate continuing education units (CEUs).

Recommendations for Further Study

This research examined three variables: CU, E_f, and PM, for the convenience of the analytical method. However, process flexibility (P_f), LT, and OC are variables that could have varying correlational dimensions with modularity; and are worthy of inclusion in future study of modularity practice in the context of CMOs. Process flexibility is the number of discrete part types producible by a system per unit time (Sethi & Sethi, 1990; Tsourveloudis et al., 1998). In a manufacturing system, P_f is a measure of discrete part types a particular machine center can produce within a period. Pf relies on time, and may benefit or suffer from the system's decision making process.

Potentially, autonomy and decision making are common to P_f and modularity. Autonomy is a characteristic of modularity and may affect process flexibility in a manufacturing organization. Wang et al. (2014) defined *autonomy* as the ability for organizations to operate independently as they pursue the satisfaction of their customers.

Operating with some autonomy may lead to flexibility in decision making. The result is value maximization and the creation of competitive edge according to Wang et al. (2014). However, the absence of empirical data substantiating the interaction between Pf and modularity creates a void in the body of knowledge. Empirical study of the link between Pf and modularity in CMOs is desirable.

Lead time (LT) is the period between the release of a new order to production and completion (Jacobs et al., 2010). But de Treville et al., 2014 isolated manufacturing LT, referring to it as the elapsed time between committing an order to production and the time of completion and ready for delivery. Jacobs et al. (2011) adopted a definition based on competitiveness; they defined LT as a rapid and effective response to demand changes. The similarity among these studies is that none focussed on modular organizations.

Recently, researchers have studied LT in relation to manufacturing agility (Jacobs et al., 2010), made-to-order manufacturing systems (Ioannou et al., 2012), lean manufacturing (Ghosh, 2013), increased productivity (Shamsuzzoha, 2011), and demand volatility (de Treville et al., 2014). However, none of these studies focused on modular companies despite the popular belief that (a) modularity increase a company's adaptability to external volatility (Bask et al., 2011; Gomes et al., 2010; Sanchez et al., 2013), (b) LT requires a method for adapting estimates to made-to-order systems in the current state of the manufacturing system (Ioannnou et al., 2012), and (c) agility is achieved by product decomposability wherein modules built in parallel without assembly problems decreased LT (Jacobs et al., 2011, Shamsuzzoha, 2011). Accordingly, the following areas with a focus on CMOs warrant more study: (a) the positive connection between product modularity, manufacturing agility and decreased LT, and (b) LT with respect to organizational performance.

Overhead cost. Manufacturing or production OC include all production costs that do not relate directly to output (Kren, 2014). Because manufacturing OCs are indirect (i.e., there is no simple, direct, and unproblematic relationship between products and costs), they pose challenge to cost allocation, planning, and control (Bengu et al., 2010). Recent research on overhead manufacturing cost includes efficiency and manufacturing overhead (Kren, 2014), misapplied capacity (Snead et al., 2010), cost stickiness (Ghaemi et al., 2012), and step-down methods for allocating OCs (Bengu et al., 2010). The gap remains to date, of manufacturing OCs with respect to agile or modular systems. A study to ascertain, if, modular and agile systems have their own specific considerations when figuring indirect and OC allocation is a viable topic for future research.

Conclusion

The concept of modularity is known across many disciplines. Still the knowledge and application of modularity is yet to diffuse the CMOs. This study findings, the differences in the metrics, between modular and nonmodular departments inform how important it is for decision and policy makers in businesses to understand the concept of modularity. The recommendation for action includes making this knowledge available through more research, lectures, and creation of curriculums in tertiary institutions of learning.

The analyses of data for this study suggest that there is significant value in modularizing CMOs. Each aspect of the results of this study finds support in prior scholarly work. For example, I found that modularity has a positive effect on CU but the effect diminishes with E_f and PM; the metrics assessed exhibit disparities. Apparently, modularity is not a panacea for all organisational problems. Thus, the need for more empirically-based studies and the enlightenment programs.

In this quantitative quasi-experimental study, I addressed the gap in the literature as it pertains to modularizing CMOs. I assessed the significance of modularizing CMOs by statistically analyzing productivity metrics between modular and nonmodular departments in a focal CMO. This study is a contribution to the needed empirically-based research on the concept and implementation of modularity in CMOs.

The promise of modularizing CMOs is enormous, and the knowledge of it is desirable for reasons including the survivability, profitability, and social change implications. Successful adoption of modularity by CMOs may lead to the continued existence of the organizations. The social implication is that more people –are employed, have a better standard of living, have better health, and get out of poverty. The results of this study are evidence and rationale to conclude that there are significant values in modularizing CMOs.

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