Engineering Management Report

The Outsourcing of Research & Development at Large United States Based Manufacturing Companies: Sound or Unsound?

James O'Flanagan
Student No. 1243908

Engineering 4100-697
Dr. Subramaniya Hariharan, Dr. James Divoky
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I. INTRODUCTION & PURPOSE

Throughout the first half of the twentieth century prosperity in the United States was great. Established American manufacturing companies like Goodyear, GM, Ford, and Chrysler employed hundreds of thousands of Americans in factories and research centers scattered across the country. Innovation was a hallmark of these companies. The big three automakers produced cars that Americans wanted to buy like the Mustang and the Continental. Goodyear produced tires that went an acceptable amount of miles and performed quite well. The people who designed and built these products formed a solid middle class in the United States. Since consumer spending comprises 70% of the U.S. Economy ([8] Cuoto 7), these workers who drove the economy with their spending, ushered in a standard of living unseen in the U.S. up until that time. But this was not to last.

During the 1970s the prosperity began to turn sour. The oil shocks from the suddenly powerful Middle Eastern countries such as Saudi Arabia and Iraq caused the U.S. economy to stagflate[1]. The Federal Reserve began to raise interest rates to counter the stagflation threat. It raised the main interest rate to nearly 20% by 1980 ([35] Sudhian). This had its intended effect of lowering the inflation portion of stagflation, but then had the unexpected consequence of causing particularly severe recession. This had the effect of killing demand as the new middle class had lost purchasing power through the inability to borrow. This caused a crisis among large U.S. manufacturers such as the aforementioned big three automakers. Revenues and profits dropped ([35] Sudhian).

[1]Stagflation is a condition of slow economic growth and relatively high unemployment - a time of stagnation - accompanied by a rise in prices, or inflation.

Profit growth now had to come in the form on new efficiencies. One large effect of the prosperity of the first half of the twentieth century was the rising salaries of designers and manufacturing workers, especially compared to any other country in the world. The U.S. manufacturers saw an opportunity to close U.S. plants and design centers and move them to lower cost, lower salary countries such as Mexico, Singapore, and China. Amazingly at the time, General Motors closed down 10 factories at once in Flint, Michigan and moved the work to Mexico ([35] Sudhian). This was further accelerated in 1994 passage of the North American Free Trade Agreement, or NAFTA.

The 1990s saw new prosperity for U.S. workers in the form of the so called "dot-com" boom. There was a fear that there would not be enough skilled computer programmers and other technical people to do the work necessary to keep up with the large infusion of capital into the sector. The U.S. market had learned from their foray into outsourcing manufacturing in the 1980s. The infrastructure was already in place to outsource the work of U.S. employees. "Instead of hiring one engineer in the United States for $70,000, it was now possible to hire 10 engineers for the same amount of money in a developing country," ([35] Sudhian) And this is exactly what was done.

The 2000s pushed along this progression. First outsourced were manufacturing in the 1980s, then lower tech but still skilled positions such as call centers and some programming in the 1990s. In the most recent decade even more skilled jobs were being outsourced, and this included entire research and development teams from the traditional manufacturing companies. The work force overseas had evolved as well. Highly skilled, educated people were now widely available, especially in countries that had recently opened their economic borders like India and China.

Jobs that were previously unable to be outsourced, like core product design work, are now being outsourced. In particular, finite element analysis (FEA) is being outsourced [2] by research and development centers. The traditional U.S. manufacturing companies are now soliciting bids to do this design work from companies such as Mahindra Satyam, Geometric Support Services, and Tata Consultancy Services. With traditional accounting R&D expense are entered on the income statement as an expense as soon as they are incurred, as per GAAP rules ([16] Harrison 337). The expensed research and development costs usually go down for the R&D division when expensive items such as inhouse FEA work are taken off the income statement and replaced by an outsourcing entry. But the U.S. manufacturer must ask themselves these questions: 1) is this actually helping our income statement, 2) is it advantageous to keep some of the core product development in house, and 3) what hidden costs are associated with outsourcing research and development for the core product? With some background, the reader now has some perspective on this study, which attempted to answer the aforementioned questions along with the overall goal of examining the soundness of outsourcing finite element work.

[2] Finite Element Analysis (or FEA, FEM), as defined in the Cook text, "is a method for numerical solutions to field problems." It determines the spatial distribution of one or more dependant variables such as heat, stress, or displacement ([6] Cook 5).

II. METHODOLOGY and DESIGN

The issue investigated was whether U.S. Fortune 500 manufacturing companies like Goodyear have a larger or smaller overall cost for the same FEA resource whether it is outsourced to an offshore company as opposed to doing it internally. The method to complete this study was conducted as follows. The first task was to define "large U.S. manufacturing firm." For the purposes of this study, this included any Fortune 500 company that derives a significant portion of its gross revenues from traditional manufacturing. Natural candidates included the big three automakers like Ford, Chrysler, and General Motors. Ford and General Motors were in fact included in this investigation. However, Chrysler could not be included due to a lack of published financial data in the past few years. This was due to the fact that Chrysler was taken private in 2007 by Cerberus Capital Management. Goodyear and IBM were also chosen. A study was found in Industry Week magazine profiling some of the largest and most successful U.S. based manufacturing firms. This list helped to round out the ten firms that were chosen. The list is as follows:

	Company Name
1	Goodyear
2	International Business Machines
3	General Motors
4	The Ford Motor Company
5	Kellogg Company
6	Apple, Inc.
7	Nike Inc.
8	Lockheed Martin Corporation
9	PepsiCo.
10	United States Steel Corp.
Source:	Industry Week magazine [19]

The availability of data pertaining to these company's outsourcing activities was initially questionable, so it was thought that the list may have to be expanded to include firms in the Fortune 1000 list. Hence, the definition of "large U.S. manufacturing firm" may have been expanded. This did not turn out to be the case.

The annual reports of the ten large firms selected were examined to determine if the manufacturing unit of any company needed to be examined separately. For example, it would not be useful to study General Motors as a whole because that would include non-manufacturing divisions such as GMAC (although it is acknowledged that General Motors spun this division off last year); or in recent years Chrysler has been variously owned by foreign companies like Daimler or private equity firms like Cerberus. This study attempted to focus only on the U.S. car manufacturing portion of the company. From the list of ten manufacturing companies an effort was made to determine the average cost of inhouse research and development cost of the FEA support in question. This was inferred from the research and development expense that was present on all ten companies' annual report. Nike was the exception, as they published this data separately, along with their number of employees. This cost is summarized later in this document to include overhead costs needed to provide FEA support such as capital expenditures on information technology. The result of this examination is a per hour rate in U.S. dollars.

After a nominal cost was established that the ten firms pay inhouse, the inverse side of the thesis was examined. The per hour rate that was charged by the outsourcing firms such as Satyam needed to be established. This rate is what one of the ten firms in question would have pay to do research and development finite element work. Eight outsourcing companies that provide finite element support were selected. This list already included the previously mentioned Mahindra Satyam, Geometric Software Solutions, and Tata Consultancy Services, which are all in business with The Goodyear Tire & Rubber Company. Five others were selected based upon availability of quotes. A combination of internet searches and phone solicitations was conducted. The list of those companies in this study is as follows:

Outsourcing Vendor
Tata Consultancy Services
Geometric Software Solutions
Mahindra Satyam
RHS Engineering Services
Yantram BPO Services LTD
Outsourcing Engineering Services
FEAMax Engineering Solution
Outsource2India.com

The data collected were the publicly quoted rate for these FEA services. Other factors related to the overall costs associated with managing an outsourced project were also included. These are the location of the company in proximity to the United States, the management efforts required of the United States Company requesting the FEA support, and the computer hardware and other capital expenditures that are necessary. An equivalent hourly rate, in U.S. dollars, was calculated for services rendered that takes into account the aforementioned overhead that the outsourcing services require.

Given the output of the study, which is the hourly rates of both the in-sourced FEA support by U.S. companies and those calculated from the outsourcing companies, a real comparison was conducted in the findings and conclusion section. Conclusions were then drawn as to which service is cheaper in real dollar is terms to the U.S. based manufacturing companies and appropriate recommendations made.

III. LIBRARY & GENERAL RESEARCH

A list of companies fitting the definition of "large U.S. manufacturing firm" needed to be generated. This required the advice of two sources. The first was a report published in Industry Week magazine which analyzed the top 50 manufacturing firms ([19] Industry Week). A few promising companies were chosen from this list. The second was Fortune Magazine's Fortune 500 list. The firms chosen from Industry Week were cross referenced with The Fortune 500 to make sure they appeared in both studies. The Fortune 500 data acquired included data going back to 1955; however the fiscal years 2008, 2007, and 2006 were the years on interest to this study.

Personal Experience

Experience was also drawn from experience of James O'Flanagan and his employment at The Goodyear Tire & Rubber Company. His employment began at the company in 2001 and continues through the present. Pertinent information from this experience included price quotes from Mahindra Satyam, Geometric Software Solutions, and Tata Consultancy. Experience was also drawn from outsourcing some of Goodyear's work to offshore companies.

University of Akron Texts

The results of this study come from current articles as well as texts previously studied in the pursuit of a Master's of Science in Engineering Management degree at the University of Akron. As is outlined on the University of Akron website ([10] Engineering Management Report Step-by-Step Guidelines), texts containing both engineering and business information were deemed pertinent. As such, most of the texts required for this degree were used.

The textbooks dealing with engineering were examined first. The most important was the text used for both the Finite Element Analysis I and Finite Element Analysis II courses at the University of Akron, called Concepts and Applications of Finite Element Analysis. This text was used to cite specific finite element related topics such as meshing ([7] Cook 1), and the decision to use either an iterative or an exact solver ([7] Cook 300). Topics of interest to outsourcing were the sources of error in the finite element method ([7] Cook 300), the rate of solution convergence ([7] Cook 310), and the advantage of symmetry in simplifying the finite element analysis ([7] Cook 55-57, 628). The Cook text also dealt with optimizing the degrees of freedom in a mesh, which would simplify an outsourcer's work ([7] Cook 156, 157). This was of particular interest to modeling something such as a tire, since radial symmetry reduces the complex mathematics of the solution. The mathematics and calculus equations necessary to support the finite element calculation were buttressed by the lessons in Schaum's Outline of Advanced Mathematics for Engineers and Scientists ([34] Spiegel). The next textbook examined was Mastering CAD/CAM by Zeid [5]. In this text, some of the software used to create new products and projects is explained like Project Data Management (PDM) systems ([5] Zeid 768) and Product Lifecycle Management (PLM) systems ([5] Zeid 905). These systems provide the data necessary to project managers to make decisions on technical aspects of a project as well and financial decisions such as equipment purchase. Any outsourcing work would have to interact with these systems to some degree which naturally leads to increase the overall cost of an outsourcer's work. The Zeid text also explains the CAD/CAM/CAE process ([5] Zeid 6) and how the finite element method fits into the overall product design framework. The most important topic in this text is the first step of finite element method, which is the creation of the geometry that is then fed to the finite element mesher and solver. The geometry is created in the company's CAD system. The book specifically mentioned Pro/Engineering, Solidworks, and Catia as some common packages. The outsourcing company needs to be proficient in any one of these systems to be effective. After the finite element method is completed a bill of material is then generated and sent to the plant to be built ([5] Zeid 104, 671). Of particular interest to outsourcing this work is that the element size, solution accuracy, and solver type must be communicated to the outsourcing vendor ([5] Zeid 712). Continuum Mechanics for Engineers was the next text to be examined. It spelled out the difference in the stress-strain curves between linear ([25] Mase 329) and non-linear ([25] Mase 301) elastic materials. If a finite element modeler needs to model a viscoelastic material such as rubber, a much more complicated solver is needed. The viscoelasticity of rubber is further explored in Mechanics of Pneumatic Tires by Clark, in that a viscoelastic material contains properties of both a fluid and a solid, and as such is non-linear in its material properties. This further complicates the finite element modeling of such a substance ([6] Clark 20). The mathematics needed to define the finite element method such as partial differential equations and sign conventions were explained in The Standard Handbook for Engineers ([24] Marks) and Schaum's Outline of Advanced Mathematics for Engineers and Scientists ([34] Spiegel). The Standard Handbook for Engineers also explained the ANSI standard, which governs file formats and program structure when setting up a custom finite element solver ([24] Marks' 2-1). Many companies' custom finite element solvers, so file and data transfers between the various programs must follow the ANSI standard to be compatible. If the outsourcing company happens to be using a different or custom solver, having the data formatted in the ANSI standard would help them get up to speed quicker. This saves the U.S. firms time and money when conducting outsourcing. The textbook Mechanics of Materials further explained the physics behind a fatal condition for a finite element solver called a zigzag or "hourglass" condition. Hourglass is a case in which an element binds up to an almost infinitely stiff material. This can poison the rest of the mesh with spurious strains and provide incorrect finite element results ([14] Gere 42). If not properly explained to an outsourcing provider, this would potentially bring their outsourcing services to a standstill. This text also explains the other assumptions made in a finite element model. Plane stress or plane strain conditions are used for symmetry ([14] Gere 474, 516). These symmetry conditions provide for time savings to an outsourcing company by simplifying the complexity of the finite element mesh. Digital Computer Methods in Engineering by Hovanessian explained matrix calculation and The Fourier Transform's usefulness in conversion between the time and frequency domain ([17] Hoavanessian). These techniques are also useful for simplification when programming a finite element solver. One topic that is usually not covered in school materials is the physics of composites. This topic was dealt with in Primer on Composite Materials: Analysis, by Asthon ([1] Ashton). Some materials, such as tire belts and plies, contain two or more substances like rubber and fabric and often behave as more than the sum of their parts ([1] Ashton 30). The stress-strain curve used in finite element modeling is different and is sometimes characterized as Hooke's law, which describes a certain relationship between stress and strain ([1] Ashton 11). Membrane bending moment is also discussed in relation to its use in representing the fabric in a composite material. These reinforcements in the rubber are often modeled as shell or membrane elements. All of these topics are difficult to explain to an outside source vendor and would cost significant amounts of money to explain and train them to perform.

The second type of texts that were investigation was the business texts that comprised the management section of the engineering management degree. These texts were Basic Marketing ([5] Cannon), Financial Accounting ([16] Harrison), Macroeconomics ([23] Mankiw), Microeconomics ([4] Brue), Business Driven Information Systems ([3] Balztan), and Fundamentals of Corporate Finance ([38] Brealey). The first of these texts, Basic Marketing, explained how a U.S. company would market and solicit bids for their engineering and finite element work ([5] Cannon 284). It also explained how the marketing department of a company drives a large portion of their research and development efforts. This has changed as companies formerly let the production and engineering divisions of a company define their strategies; now the business strategy starts with the customer and what they demand from a firm ([5] Cannon 284). The second text, Financial Accounting, explained how to read a company's financial statements, starting with the definitions of Generally Accepted Accounting Practices ([16] Harrison 9). The authority of FASB to draft these rules comes from the U.S. based companies themselves ([16] Harrison xxvii). The most important point from this text was where to find the research and development costs are located on the financial report ([16] Harrison 337). Macroeconomics and Microeconomics explain the how cost of capital relates lower inhouse costs resulting from outsourcing ([23] Mankiw 466, [4] Brue). The Microeconomics text by Brue actually contradicts Cannon in that product innovation in research and development will actually drive demand instead of demand (or marketing) driving design ([4] Brue 267). Brue goes on to explain how a patent is actually a tangible asset that should show up on the balance sheet ([4] Brue 268). This is one of the only products of research and development that end up as an asset however. The Business Driven Information Systems text is valuable in defining the costs of outsourcing in that an Enterprise Resource Planning (ERP) system must be implemented to communicate with outsourcing vendors such as those that conduct finite element research ([3] Balztan 309-310). This ERP system compliments the PLM and PDM systems mentioned previously. Finally, Fundamentals of Corporate Finance dealt mainly with the time value of money ([38] Brealey 110-112) and other types of costs such as overhead costs ([38] Brealey 262). The time value of money is the exponential increased value of money over time due to compounding interest. If product design has significant delays, whether they occur because of inhouse problems or outsourcing problems, the projects cost can quickly become over budget.

Annual Reports

A search was made for the most current annual report or SEC 10-K filing that could be found. It was found that not all companies publish an annual report per se, but a regulatory filing is always made with the Securities and Exchange Commission. As such, either an annual report or the 10-K regulatory finding was deemed sufficient as long as a consolidated balance sheet, income statement, and statement of cash flows were present. As stated previously, the most up-to-date financial information was considered for this investigation. This meant that the most recent full year financial data was 2009. However, having begun this investigation early in 2010, it was found that two companies, PepsiCo and The Ford Motor Company, had not yet published their annual report or file their 10-K with the SEC for 2009. Thus the most recent data available for all companies was for the 2008 fiscal year. All ten companies published either annual reports or 10-K filings for that year as well as 2007 and 2006.

As stated on Harrison 337, research and development costs are usually shown as a one time, yearly expense rather than shown as an investment and subsequently entered on the balance sheet as money spent in development of an asset ([15] Harrison). Exceptions to this rule do exist. For example, if a firm is able to stipulate in a contract that R&D costs will be recovered from a customer, then it is shown as an asset in the balance sheet in accounts receivable ([15] Harrison 6, 337). Another example would be if a company could quantify the dollar value of a patent or other intellectual piece of property prior to an imminent sale of said piece of intellectual property ([15] Harrison 335). Given these limitations, it was known from the start of this investigation that the research and development costs of each company would be hard to determine. Nevertheless, the attempt was made. A research and development expense on the income statement or an asset shown the balance sheet was included in this analysis. Tables in Appendix b, Figures 8-17 show the revenue, net income, cost of goods sold, and R&D expense for each company. For illustration, Appendix b, Figure 3 shows net income as a percent of revenue while Appendix b, Figure 4 shows cost of goods sold as a percent of net income as research and development expense can be a component of cost of goods sold for some companies.

The Duke Report and Other Comparative Studies

One of the most significant pieces of literature that was pertinent to this investigation was a report called "Next Generation Outsourcing" published by Lewin and Cuoto of the Duke-Fuqua School of Business in 2006 (herein referred to as The Duke Report). This was a study commissioned by the Duke School of Business to ascertain why the there was an increase of the outsourcing of skilled labor in the United States. The areas of study included information technology, business process offshoring, and research, development, and engineering. The section of interest to this study was the research and development outsourcing. The central tenant of this section is that in the past companies looked to improve by efficiency and overhead cost by outsourcing manufacturing. Countries such and China, India, and Singapore provided a cheap resource of labor, especially compared to the United States. Thus the main motivation for outsourcing was purely cost driven. The evolution of outsourcing continued into research, development, and engineering and the same was true. Engineers with a very good educational background were being hired for one sixth of their U.S. counterparts. The Duke Report counters that this premise changed in the last decade when a shortage of skilled laborers in the United States caused the manufacturing companies' motivations to change. They were no longer looking for cheaper engineering labor; they were looking for engineering skills that did not exist in the U.S. As stated on page 27, "businesses are thinking more strategically, it is not only a cost cutting tactic." A survey conducted by the report dealt with the number of advanced degrees obtained in science and engineering. It was found that the number of those degrees obtained by U.S. nationals has decreased from approximately 80,000 in 1995 to 65,000 in 2005 ([8] Cuoto

46). This happened at the same time that the estimated demand for such degrees each year increased from 80,000 to 100,000 in the same time period ([8] Cuoto 46). Clearly this gap had to be filled by some workers, so this upward pressure for the skillset required to conduct research and development in finite element has most certainly added to the outsourcing and offshoring of such jobs.

At the beginning of the new century, less than 10% of U.S. firms were pursuing outsourcing projects. By the end of the first decade approximately half of United States based companies were pursuing outsourcing projects. The same study reflects that the total number of outsourcing projects initiated by U.S. companies followed the same upward trend ([8] Cuoto 18).

Broken down by the type of work being outsourced from 1990 to 2006, information technology was by far the most prevalent. With the data following an approximately parabolic path, 3% of information technology firms outsourced projects while 50% outsourced them in 2006 ([8] Cuoto 19). Other types of work followed a similar path in the same time period. Administrative work such as human resources, call center work; and product design, research and development all increased from a few percentage points in 1990 to almost half of all projects being outsourced fifteen years later.

The Duke Report also looked at the perceived risks of outsourcing. The main risks include attaining and retaining service quality for jobs like call centers; keeping data communication with the U.S. companies secure, keeping the processing of data at offshore locations secure, and the perceived loss of managerial control ([8] Cuoto 65). The study purposefully includes the word perceived in the title of this section, "Perceived

Risks," ([8] Cuoto 65). The security issues have been resolved with such technologies as https communication and PGP encryption. The loss of managerial control has also been addressed as the quality of communication has increased the ability of a United States based manager to control a project based in India or the Philippines on a daily or hourly basis.

Another report that deals with the comparison of insourced versus outsourced research and development work (and by extension, finite element work) is the Prahalad report entitled, "The Core Competence of the Corporation." This report attacks the problem from an angle of core competencies. As defined in the study, core competencies are any trait or property that makes a company unique ([30] Prahalad 2). For example, a manufacturing company's core product like a tire would make it unique because even though there are other tire manufacturers, and presumably do not offer a product mix that is identical, this companies product design and delivery system is unique ([5] Cannon 192). Prahalad argues that it is most often not wise to outsource **any** activity in a company which could be considered a core competency. It can be argued that the new product engine in general, and finite element work specifically, is what defines a company because it dictates to a large extend what products a company would sell. Therefore, drawing conjecture from Prahalad, it would be unwise to outsource any research, development, or finite element work.

Lastly, the quoted per hour prices were obtained through solicitation and through internet research. Of the eight companies chosen; three, Mahindra Satyam, Geometric Software Solutions, and Tata Consultancy were affiliated with Goodyear's research and development center. The quoted finite element rates were obtained from experience at

Goodyear. Mahindra Satyam in particular has a colorful past. It was founded in 1986 as Satyam Services, Inc. and rebranded Mahindra Satyam after a financial restructuring and an accounting scandal ([18] India Times). Mahindra Satyam is now part of the Mahindra Group, one of the top ten industrial firms based in India ([39] mahindrasatyam.com). Among its engineering solutions provided are finite element analysis services. They provide finite element meshing services, the ability to define materials properties such as those of rubber, steel, and various fabric cords. They also provide the ability to post process finite element results such as building pressure, stress, and displacement distribution diagrams. Geometric Software Solutions provides software code-writing support for the finite element control software. They also provide software code for post processing software and product data management software. Tata Consultancy provides statistical analysis and finite element meshing services for its customers. The five others, RHS Engineering Services, FEAMax, Yantram BPO Services LTD, Outsourcing Engineering Services, and Outsource2India.com, were chosen based on the availability of their per hour price quotes. The five of these companies provide less sophisticated levels of finite element support than Satyam, GSS, and Tata. RHS Engineering Services provides generalized running of an automeshing program and the subsequent use of a likewise automated finite element solver. FEAMax offers similar services. It appeared Yantram specialized in statistical analysis of stress/strain data through use of tools such as Microsoft Excel and SAS JMP. Yantram BPO, Outsourcing Engineering Services, and Outsource2India.com provided only generalized description of their analyses of linear elastic materials.

IV. FINDINGS

The initial research and analysis of this investigation dealt with the selection of the companies based upon their recommendation in Industry Week magazine and their Fortune 500 ranking for 2008. Table 1 in Appendix a shows the four year trend of the Fortune 500 rank of each of the ten firms selected. Appendix a, Figure 1 further illustrates this data. Ford, IBM, and General Motors all were near or in the top ten for all four years, while Kelloggs bottomed out the list in the 220 range. Most of the company's variation in their Fortune 500 rank was around 10 with the highest variation was Apple at 37 places, mostly as a result of an increases of rank. Appendix a, Tables 2, 3, 4 and 5 show the revenue produced by each of the companies for the 2006, 2007, 2008, and 2009 fiscal years respectively. These revenue values are used by Fortune magazine to compile their Fortune 500 rank.

As previously mentioned, the ultimate output of this investigation is a per hour rate for FEA work that will allow an apples-to-apples comparison of insourcing and outsourcing research, development, and finite element analysis work. The following two tables provide the starting point for that analysis. Appendix d, Table 20 (also included below) shows the publicly quotes rates for each of the eight firms that provide finite element outsourcing support. This data is further illustrated in Appendix d, Figure 6. The highest quoted price was $60/hour, provided by both Tata Consultancy and Geometric Software Solutions; the lowest was $15/hour, provided by Outsource2India.com, giving a spread of $45/hour in the prices. The average price was $39.38, which was the rate used in the comparison to the inhouse FEA work.

Table 20

Outsourcing Vendor	$ Per Hour of FEA work	Source
Tata Consultancy Services	$60.00	The Goodyear Tire & Rubber Company
Geometric Software Solutions	$60.00	The Goodyear Tire & Rubber Company
Mahindra Satyam	$50.00	The Goodyear Tire & Rubber Company
RHS Engineering Services	$20.00	http://www.rhs-services.com/Services.htm [32]
Yantram BPO Services LTD	$35.00	http://architectural-design.outsourcing-services-india.com/price.php [31]
Outsourcing Engineering Services	$25.00	http://www.outsourcingengineeringservices.com/ [28]
FEAMax Engineering Solution	$50.00	feamax.com [9]
Outsource2India.com	$15.00	outsource2india.com [27]
Average	$39.38	
Std Dev	$18.02	
High – Tata, Geometric	$60.00	
Low – Outsource2India.com	$15.00	

The insourced FEA work was a little more challenging to calculate. The concept of an FTE, or full time equivalent, was used. The term full time equivalent is defined as the yearly number of hours that one worker would perform ([16] Harrison 242). In order to calculate this quantity for each company, it was necessary to find the real number of dollars spent for each person working in research and development. This was done in a Microsoft Excel sheet that was copied here as Appendix c, Table 19 and also shown below. Table 19 contains only the information available in the firms' 2008 10-K annual reports. This data is further illustrated in Appendix c, Figure 5. The calculation started with the total number of employees and the 2008 expense for research and development. A ratio was then calculated comparing the R&D expense versus total revenue for that 2008 fiscal year, producing a percentage. This calculation was illustrated in Appendix c, Table 18, and a graph shown in Figure 2, Appendix c. This percentage was then used to calculate the number of dollars spend per year on one employee. A generalized number of 1800 hours per employee per year was assumed and an hourly cost for each employee was obtained. Please see Table 19 for details. Of the ten firms examined, the average R&D expense as a percent of revenue was 3.07% with a standard deviation of 1.87%. The high belonged to IBM at 6.12%, the low belonging to PepsiCo at 0.90%. The lowest per hour cost for an FTE was PepsiCo at $121.37 while the highest was Apple coming in at a staggering $514.28. The average per hour cost for one FTE was $260.74 and the standard deviation of that calculation is $127.65. The average figure of $260.74 was used for calculations in the rest of the study and as a comparison the outsourcing hourly rate. This figure represents that average per hour cost of 1 hour of time for a research and development engineering employee. It was assumed that this was the cost for 1 hour of FEA work as well since all engineering hours are considered the same for budgetary and accounting purposes. This assumption was derived from experience at Goodyear. The initial comparative figure to start with was that 1 hour of outsourced FEA work was $39.38, while the average cost for 1 hour of FEA work performed in house was $260.74. These two numbers were used for the comparative study.

Table 19

Company Name	# Employees in 2008	R&D Expense for 2008	% Revenue Spent on R&D	# FTE's in R&D based on Revenue	$ in 2008 for 1 FTE	# Hours for 1 FTE	Per Hour Cost for 1 FTE
Goodyear	75000	$366,000,000.0	1.88%	1409	$259,758.69	1800	$144.31
International Business Machines	398455	$6,337,000,000.0	6.12%	24366	$260,075.52	1800	$144.49
General Motors	243000	$8,000,000,000.0	5.38%	13065	$612,323.00	1800	$340.18
The Ford Motor Company	213000	$7,300,000,000.0	4.97%	10594	$689,069.28	1800	$382.82
Kelloggs Company	32000	$181,000,000.0	1.41%	452	$400,442.48	1800	$222.47
Apple, Inc.	35100	$1,109,000,000.0	3.41%	1198	$925,709.52	1800	$514.28
Nike Inc.	32500	$187,270,000.0	1.00%	325	$576,215.38	1800	$320.12
Lockheed Martin Corporation	146000	$1,220,000,000.0	2.86%	4168	$292,706.33	1800	$162.61
PepsiCo.	198000	$388,000,000.0	0.90%	1776	$218,468.47	1800	$121.37
United States Steel Corp.	49000	$625,000,000.0	2.78%	1363	$458,547.32	1800	$254.75
Average	142206	$2,571,327,000.0	3.07%	5872	$469,331.60	N/A	$260.74
Std Dev	121481	$3,245,365,595.6	1.87%	7874	$229,767.00	N/A	$127.65
Max	398455	$8,000,000,000.0	6.12%	24366	$925,709.52	1800	$514.28
Who's Max?	IBM	GM	IBM	IBM	Apple	N/A	Apple
Min	32000	$181,000,000.00	0.90%	325	$218,468.47	1800	$121.37
Who's Min?	Kelloggs	Kelloggs	PepsiCo	Nike	PepsiCo	N/A	PepsiCo

Difficulties in Outsourcing FEA work

The University of Akron texts were used to flesh out some of the more technical aspects of finite element work. A step-by-step process for completing an FEA project was put together from these texts and an estimate on the number of hours to complete each task for the purpose of assigning a cost to it. Also, only structural/mechanical finite element analysis was considered for this investigation. There were four topics in finite element analysis that were directly applicable to the ability or inability of a firm to outsource this kind of work

The first of these areas is the meshing of the given geometry and meshing standards that must be communicated to an outsourcing company. A mesh for finite element purposes is considered to be the discritization of a given solid geometry ([6] Cook 242). The insourced as well as the outsourced employee must consider where in the structural geometry to put either a course mesh or a fine mesh. Usually the mesh needs to have comparatively smaller elements in the areas where there are sharp geometric changes. The mesh also needs to be finer to capture material changes. This is especially true in a composite structure such as a tire, where there are many material changes in a small geometric area.

The second area of interest pertains to material properties. Simple finite element analysis done can be done on a material such as steel with off-the-shelf products such as Solidworks Simulation Xpress or any number of the Algor distributions such as those that plug into Pro/Engineering or NX5. In most applications steel is a linear elastic material that basically acts as a spring under load with no hysteresis loss ([14] Gere 777). Other materials such as plastics behave in nonlinear ways such as hardening and energy loss due to hysteresis where the material has a time history ([7] Cook 604, 601). Others materials like rubber act under the viscoelastic regime and have properties of both liquids and solids ([6] Clark 20). These types of constitutive models that represent nonlinear material properties are usually highly proprietary and developed inhouse by one of these U.S. manufacturing firms. This relates to the outsourcing of this work because long, painstaking processes need to be taken to ensure that either a) the outsourcing company operates the finite element software from a "blackbox" and never has access to the inner coding of the constitutive equations, or b) complex nondisclosure agreements must be drafted by lawyers for the U.S. manufacturing firm. In either case, a considerable sum is spent up front by the company looking to outsource work. Admittedly, this cost is hard to quantify, but it is a real cost.

The third topic of interest is the nonlinearity of the structural geometry and material properties. This is especially important in a composite structure ([1] Ashton 1-5). For example, the steel belts pictured below in Figure 7 have reinforcement material steel embedded in the rubber. By themselves, the steel strands have a given stiffness. But as they were set in a certain geometry in opposing angles to each other, the overall stiffness of the structure is increased dramatically ([6] Clark 219). When outsourcing, these types of composite structure properties must be communicated and understood by the outsourcing company.

Figure 7 – Composite Structure

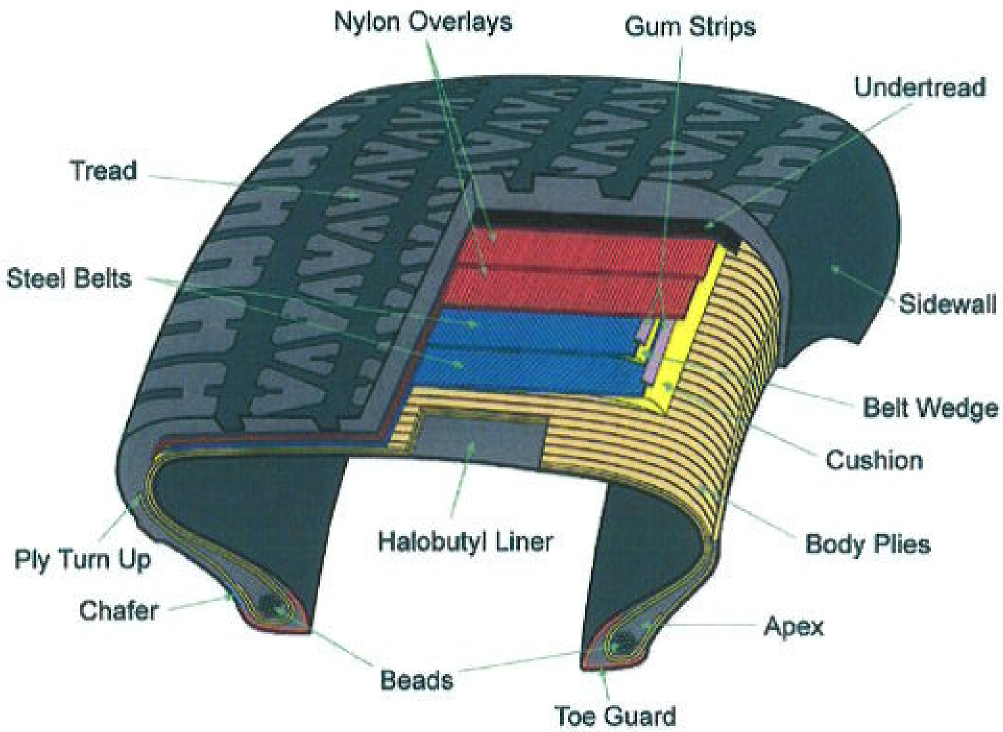

Image Source: http://www.tirefailures.com/images/TireCutaway.jpg

Lastly, the choice of solver, it not already decided upon, it critical in the communication between the manufacturer and the outsourcing company. Some finite element work can be done entirely by the outsourcing company. As previously mentioned, for something simple and nonlinear like the stress analysis of a static steel motor block, an off-the-shelf solver could be used. The automeshing capability of such a tool would be able to handle most analysis requests. On the contrary, non-standard analysis requests come along that contains material non-linearities, geometric non-linearities, or both. In non-linear situations, two types of solver can be considered, explicit or implicit ([7] Cook 78). The first is directly solving for the stiffness displacement matrix [X] in the [F] = [K][X] equation. This is called an explicit or direct solver. This functions by using time on a computing cluster mainly to find the inverse of the [K] matrix to solve for the displacement matrix. A trait of this type of solver is that it will always have a predictable, but long execution time. This is especially true in a model with a high number of degrees of freedom on the order of a few million. Conversely, the implicit solver guesses the displacement matrix and iterates to the correct solution inside a given tolerance vector. The execution time could be shorter or longer, but in modern implementations shorter is the rule of thumb. In relation to outsourcing, if these nonlinear properties exist a significant investment of money must be made to ensure the outsourcing company can perform the analysis needed.

The Average Tire Project 1

An example project was used to determine some of the costs associated with the outsourcing project. This example, entitled "Average Tire Project 1," broke down the finite element modeling of a typical passenger tire. Two different iterations of the project were considered. The first, in Appendix e, Table 21 (and shown below), outlines the Average Tire Project 1 that was outsourced. This project was still managed behind the scenes by the inhouse employees. The second iteration of Average Tire Project 1 was done completely by a typical inhouse engineer at a large U.S. manufacturing firm and shown in Appendix e, Table 22 (show below as well). These tasks were then assigned a number of hours and cost based upon what is done on a finite element analysis of a tire. This example project entailed taking a known geometry of a passenger tire, with known material properties and constitutive material models, and outsourcing it to any one of the eight outsourcing vendors that were chosen. In Appendix e, Table 21 (shown below), the outsourced version of Average Tire Project 1 is shown. The tasks are shown in descending chronological order. Some of these tasks required either supervision or intervention from an inhouse employee and are marked either "In" or "Out." Hours to complete each task were assigned and the appropriate per hour rate was used to calculate the cost of that task (whether inhouse or outsourced). Those costs were summed up and the total project cost was found to be $7999.86. One item of note is the cost of overhead information technology support that was broken out from the total cost. Without the IT costs associated, the total project cost of the outsourced Average Tire Project 1 was $3828.02. Whether this cost should be included is one large item of debate. One last item that was calculated was the combined final per hour rate of the project. It contained insourced and outsourced components as well as the overhead IT costs. It took 41 hours to complete the project. The hourly rate was $195.12.

Table 21

Average Tire Project 1, Outsourced and Managed by Inhouse Employees					
Activity	Inhouse Activity or Outsourced Activity?	# Hours	Average Inhouse FTE Rate	Average Rate Outsource	$ Cost @ Average FTE Rate
communication of geometric data from product design	In	3	$260.74	$39.38	$782.22
define material properties	Out	1	$260.74	$39.38	$39.38
meshing	Out	5	$260.74	$39.38	$196.88
define BC's, LC's of road, hub, and tire/vehicle weight	Out	5	$260.74	$39.38	$196.88
Management Check Conference Call for BC's and LC's	Out	3	$260.74	$39.38	$118.13
Management Check Conference Call for BC's and LC's	In	3	$260.74	$39.38	$782.22
Run Solver	Out	5	$260.74	$39.38	$196.88
Troubleshoot Solver Run	Out	4	$260.74	$39.38	$157.50
Post Process	Out	4	$260.74	$39.38	$157.50
Format & Check in Results	Out	4	$260.74	$39.38	$157.50
Inhouse post processing check	In	2	$260.74	$39.38	$521.48
Inhouse communication of Results to product design	In	2	$260.74	$39.38	$521.48
Cost for IT ****	In	16	$260.74	$39.38	$4,171.84
Total		41			$7,999.86
Total w/o IT costs					$3,828.02
Equivalent Per Hour Cost					$195.12
Equivalent Per Hour Cost w/o IT					$93.37
****This attempts to include large capital expenditures for computer hardware & software to run FEA solver					

Appendix e, Table 22 shows the insourced, or inhouse version of the same Average Tire Project 1. Since minimal inhouse supervision of a project was required, some of those tasks were unnecessary and removed. The only per hour rate that was applicable here was the average inhouse rate of $260.74. The total project cost was $6257.75. The total hours spent on the project was 24 hours for a final equivalent rate of $260.74.

Table 22

Average Tire Project 1, Done by Inhouse Employees					
Activity	Inhouse Activity or Outsourced Activity?	# Hours	Average Inhouse FTE Rate	Average Rate Outsource	$ Cost @ Average FTE Rate
communication of geometric data from product design	In	1	$260.74	$39.38	$260.74
define material properties	In	1	$260.74	$39.38	$260.74
meshing	In	5	$260.74	$39.38	$1,303.70
define BC's, LC's of road, hub, and tire/vehicle weight	In	3	$260.74	$39.38	$782.22
Management Check Conference Call for BC's and LC's	N/A		$260.74	$39.38	$0.00
Management Check Conference Call for BC's and LC's	In	1	$260.74	$39.38	$260.74
Run Solver	In	5	$260.74	$39.38	$1,303.70
Troubleshoot Solver Run	In	2	$260.74	$39.38	$521.48
Post Process	In	4	$260.74	$39.38	$1,042.96
Format & Check in Results	N/A		$260.74	$39.38	$0.00
Inhouse post processing check	N/A		$260.74	$39.38	$0.00
Inhouse communication of Results to product design	In	2	$260.74	$39.38	$521.48
Cost for IT (Overhead is already built into the $260.74 per hour figure)	N/A		$260.74	$39.38	$0.00
Total		24			$6,257.75
Equivalent Per Hour Cost					$260.74

V. **CONCLUSIONS**

The analysis of this data was conducted in two stages as previously mentioned. The first was to obtain quoted rates for the finite element work provided by the outsourcing companies while also calculating a rate that is used by each of the ten firms for internal budgeting of inhouse FEA engineers. The average per hour rate from the companies providing finite element engineering support was $39.38. The calculated value for an insourced engineer who might perform finite element analysis was $260.74. The second phase of this investigation was to define what each of these values meant and then attempt to normalize them against each other. In the current state of outsourcing, U.S. companies make comparisons only during the first phase when deciding whether to outsource. That is certainly the way it is done at Goodyear. A more reasonable method would be to normalize them against each other, then make the decision to outsource. On average, each engineering hour performed by an in house employee costs over $250 while that same work can be done by the outsourcing company for less than one-fifth of that amount. Over one year, one FTE of inhouse engineering costs $470,000 dollars while one FTE of outsourced work costs $71,000. When outsourcing is done, it is usually done on an FTE-for-FTE basis. In other words, for every $470,000 job that is shed, one $71,000 job is picked up. The conclusion is that each outsourced job saves the large U.S. manufacturing firm approximately $400,000 per year.

The second phase of this investigation attempted to make more sense of this large a discrepancy. The discrepancy is: $260.74/hour for inhouse work versus $39.38 for outsourced work; $470,000/year per FTE for inhouse work versus $71,000/year per FTE for outsourced work. This was done by analyzing the project "Average Tire Project 1."

Since both the insourced and outsourced jobs were both performing a finite element analysis, many of the tasks perform by the each were either similar or the same. There were some tasks that were performed by one and not the other. For example, regarding the outsourced task job, some supervision was needed from the inhouse employee. This was added into the final cost as time spent by both the inhouse employee and the outsourced employee, both at their respective hourly rates. Also, on the tasks that were the same, a different amount of time was spent on the task. Lastly, the hourly rate of the inhouse employee contains a large amount of overhead [4] costs, one of them being a large information technology charge. This charge is especially important to finite element analysis as a large parallel processing computing center is needed to perform some fairly average tasks. It was decided that this needed to be included in the total cost of the outsourced version Average Tire Project 1. This was done by including 16 hours of inhouse work performed for the project. With the equalizing factors taken into account, the hourly rate of the outsourced project was still less than the insourced version of the same project by about 25%, $195 versus $260. However, the total project costs were greater for the outsourced project by 25% due to the increased amount of hours spent on the outsourced project, $8,000 versus $6,200. Admittedly, this was mostly due to the added cost of the information technology support provided for in the outsourced analysis.

[4] Overhead costs may or may not be related to a particular project, but must be spent nonetheless. These costs include rent, heat, electricity, and capital expenditure related to the computing center ([38] Brealey 262). In this example, the building housing the computing center must be paid for, heated, and provided with electricity.

VI. **RECOMMENDATIONS**

The recommendation of this investigation is that it is a **sound** decision for the large U.S. manufacturing firm to pursue outsourcing of finite element analysis projects where possible. Even with a large fudge factor included to account for some of the overhead like IT support, the hourly rate is still considerably less than the per hour rate for 1 FTE of an insourced employee. The total project cost for the example Average Tire Project 1 was still greater for the outsourced version, but this can be rectified by letting the outsourced company be more autonomous when conducting their finite element analysis. This would lead to less time spent using inhouse resources to manage the project, significantly reducing the overall cost. It appears even a formerly struggling large U.S. firm, United States Steel, can benefit from outsourcing. They are currently investing in Ohio with some outsourced work in a joint venture with Japan's Pro-Tec ([33] Schoenberger).

Regarding the recommendations for the financial information, one of the limitations discussed is the lack of clarity that the Financial Accounting Standards Board (FASB) has regarding research and development expenses, costs, and assets. A clearer standard in reporting this data is needed. Since this is the data that is widely used in decisions made by investors, it would greatly expand the knowledge of the investor to use in making a decision in whether to invest in the company. A robust investment in research and development will usually indicate whether an investor will get his or her opportunity cost of capital covered ([38] Brealey 189). This clarity in data reporting would have been of some use to this thesis as well.

VII. **LIMITATIONS**

The most obvious limitation in the financial analysis was the rules that generally accepted accounting principles (GAAP) proscribes for the treatment of research and development costs. A recommendation would be to lobby for changes in GAAP rules to treat research and development spending as an investment in an asset (either tangible or intangible). It was found in the annual reports that the individual line item for a research and development expenditure was normally found buried in the last pages of the annual report, away from the main income statement. In one case, Nike Inc., it was found that an individual line item for this expense was eliminated entirely and had to be found elsewhere. Also, GAAP seems to be unclear on how to treat intellectual property. Only in one case, again Nike Inc., was there any research and development related items showing up on the balance sheet. In this case, Nike made an entry of patents as an asset in 2008 and 2007. It is not a coincidence that Nike is the only company that omitted research and development as an expense and the only one to include it in its balance sheet. This just goes to show how the ambiguity in the GAAP rules may lead to confusion.

Another limitation was the initial lack of quotes available for the finite element work. Several sites on the internet for the outsourcing vendors had some sort of place to advise the user to "contact us" for a quote on their website. This was done for a few of the non-Goodyear related companies. Admittedly, a figure given over the phone probably instills more confidence in the quoted figure.

The limitation built into the calculation of a full time equivalent employee is by definition a limitation in this type of analysis. Many of the fixed costs such as building, maintenance, IT support, security, and other items are built into an FTE. Thus it is only an estimate, and the true cost of an hour of engineering time for a U.S. manufacturing firm is proprietary in nature and is not actually able to be found from public data such as a financial statement.

The last limitation was the estimate of the amount of time that was spent on each task in the analysis of Average Tire Project 1. This was an honest assessment of the number of hours spent on each aspect of the project, but admittedly can be open for interpretation. Also, it is nearly impossible to calculate an exact figure for the overhead cost of information technology support for each project, but an attempt was nevertheless made.

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IX. **APPENDIX**

Appendix a – Fortune 500 Information

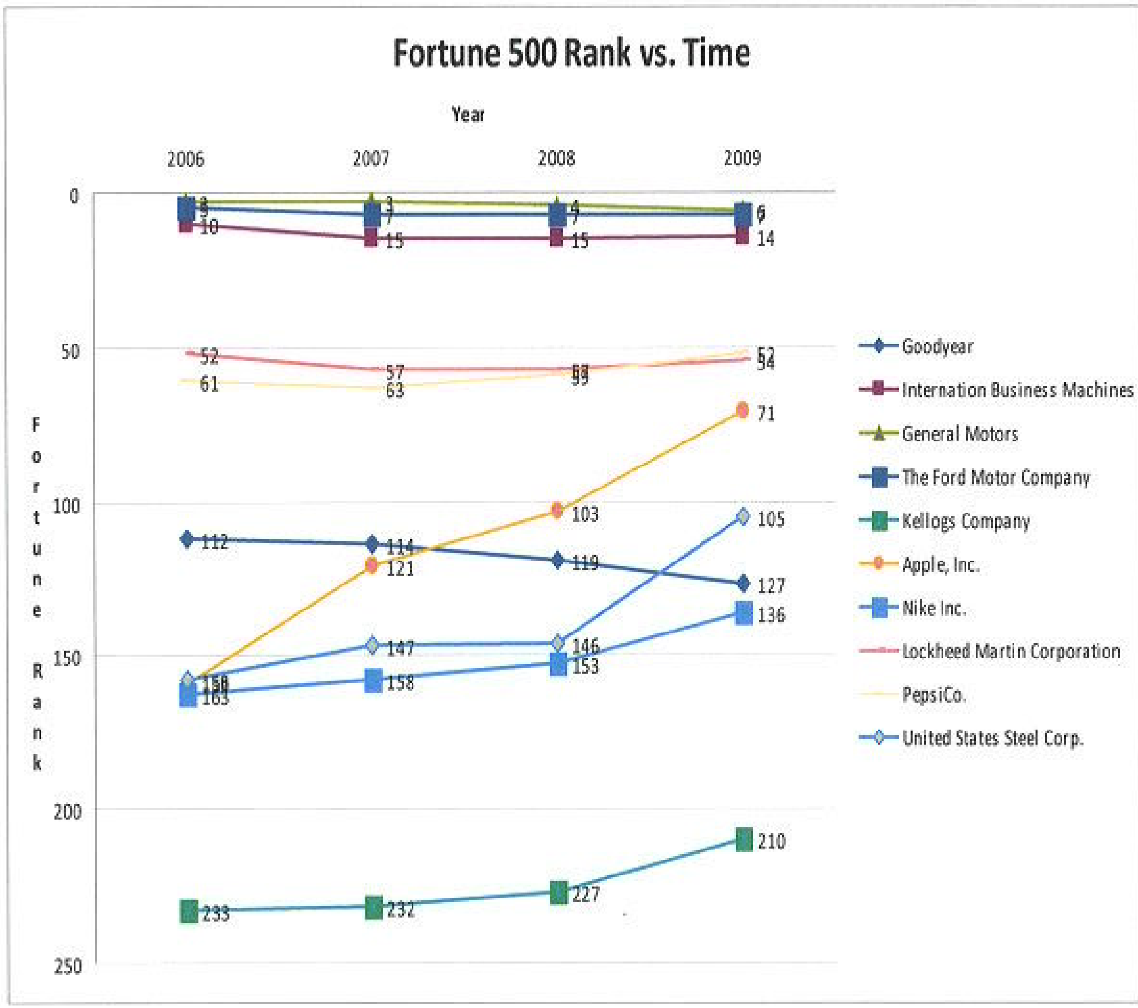
Table 1

Four year Snapshot of Fortune 500 Rank

Company Name						
	2006	2007	2008	2009	Average	Std Dev
Goodyear	112	114	119	127	118	7
International Business Machines	10	15	15	14	14	2
General Motors	3	3	4	6	4	1
The Ford Motor Company	5	7	7	7	7	1
Kelloggs Company	233	232	227	210	226	11
Apple, Inc.	159	121	103	71	114	37
Nike Inc.	163	158	153	136	153	12
Lockheed Martin Corporation	52	57	57	54	55	2
PepsiCo.	61	63	59	52	59	5
United States Steel Corp.	158	147	146	105	139	23
Source: Fortune Magazine						

Figure 1

Illustrated Four Year Snapshot of Fortune 500 Rank



Source: Fortune Magazine [12]

Table 2

2006 Fortune 500 Rank and Revenues

Company Name	2006 Fortune 500 listing	2006 Revenue ($ millions)
Goodyear	112	19723
International Business Machines	10	91134
General Motors	3	192604
The Ford Motor Company	5	177210
Kellogg Company	233	10177
Apple, Inc.	159	13931
Nike Inc.	163	13740
Lockheed Martin Corporation	52	37213
PepsiCo.	61	32562
United States Steel Corp.	158	14039
Source: Fortune Magazine [12]		

Table 3

2007 Fortune 500 Rank and Revenues

Company Name	2007 Fortune 500 listing	2007 Revenue ($ millions)
Goodyear	114	20258
International Business Machines	15	91424
General Motors	3	207349
The Ford Motor Company	7	160126
Kellogg Company	232	10907
Apple, Inc.	121	19315
Nike Inc.	158	14955
Lockheed Martin Corporation	57	39620
PepsiCo.	63	35137
United States Steel Corp.	147	15715
Source: Fortune Magazine [12]		

Table 4

2008 Fortune 500 Rank and Revenues

Company Name	2008 Fortune 500 listing	2008 Revenue ($ millions)	2008 Profit ($ millions)
Goodyear	119	20538	602
International Business Machines	15	98786	10418
General Motors	4	182347	-38732
The Ford Motor Company	7	172468	-2723
Kellogg Company	227	11776	1103
Apple, Inc.	103	24006	3496
Nike Inc.	153	16325.9	1491.5
Lockheed Martin Corporation	57	41862	3033
PepsiCo.	59	39474	5658
United States Steel Corp.	146	16873	879
Source: Fortune Magazine [12]			

Table 5

2009 Fortune 500 Rank and Revenues

Company Name	2009 Fortune 500 listing	2009 Revenue ($ millions)	2009 Profit ($ millions)
Goodyear	127	19488	-77
International Business Machines	14	103630	12334
General Motors	6	148979	-30860
The Ford Motor Company	7	146277	-14672
Kellogg Company	210	12822	1148
Apple, Inc.	71	32476	4834
Nike Inc.	136	18627	1883.4
Lockheed Martin Corporation	54	42731	3217
PepsiCo.	52	43251	5142
United States Steel Corp.	105	23754	2112
Source: Fortune Magazine [12]			

Appendix b – Financial Statement/SEC 10-K Data

Table 8

Goodyear			
(all figures in $MM)	2008	2007	2006
Revenue	$19,488.0	$19,644.0	$18,751.0
Net Income	-$77.0	$602.0	-$330.0
Cost of Goods Sold (COGS)	$16,139.0	$15,911.0	$15,726.0
R&D Expense	$366.0	$372.0	$342.0

Source: Goodyear Annual Report [15]

Table 9

International Business Machines			
(all figures in $MM)	2008	2007	2006
Revenue	$103,630.0	$98,786.0	$91,424.0
Net Income	$12,334.0	$10,418.0	$9,416.0
Cost of Goods Sold (COGS)	$57,696.0	$57,057.0	$53,129.0
R&D Expense	$6,337.0	$6,153.0	$6,107.0

Source: IBM Annual Report [20]

Table 10

General Motors			
(all figures in $MM)	2008	2007	2006
Revenue	$148,797.0	$179,784.0	$204,467.0
Net Income	-$30,860.0	-$43,297.0	-$2,423.0
Cost of Goods Sold (COGS)	$149,311.0	$165,753.0	$163,514.0
R&D Expense	$8,000.0	$8,100.0	$6,000.0

Source: GM Annual Report [13]

Table 11

The Ford Motor Company			
(all figures in $MM)	2008	2007	2006
Revenue	$146,777.0	$172,455.0	$160,065.0
Net Income	-$14,762.0	-$2,723.0	-$12,613.0
Cost of Goods Sold (COGS)	$127,103.0	$142,587.0	$148,866.0
R&D Expense	$7,300.0	$7,500.0	$7,200.0

Source: Ford Annual Report [11]

Table 12

Kellogg Company			
(all figures in $MM)	2008	2007	2006
Revenue	$12,822.0	$11,776.0	$10,907.0
Net Income	$1,148.0	$1,103.0	$1,004.0
Cost of Goods Sold (COGS)	$7,455.0	$6,597.0	$6,082.0
R&D Expense	$181.0	$179.0	$191.0

Source: Kellogg's Annual Report [21]

Table 13

Apple, Inc.			
(all figures in $MM)	2008	2007	2006
Revenue	$32,479.0	$24,006.0	$19,315.0
Net Income	$4,834.0	$3,496.0	$1,989.0
Cost of Goods Sold (COGS)	$251.0	$130.0	$89.0
R&D Expense	$1,109.0	$782.0	$712.0

Source: Apple, Inc. Annual Report [2]

Table 14

Nike Inc.			
(all figures in $MM)	2008	2007	2006
Revenue	$18,727.0	$16,325.9	$14,954.9
Net Income	$1,883.4	$1,491.5	$1,392.0
Cost of Goods Sold (COGS)	$10,239.6	$9,165.4	$8,367.9
R&D Expense	$187.3	$163.3	$149.5
Balance Sheet Patent Assets	$33.1	$31.8	N/A

Source: Nike Inc. Annual Report [26]

Table 15

Lockheed Martin Corporation			
(all figures in $MM)	2008	2007	2006
Revenue	$42,731.0	$41,862.0	$39,620.0
Net Income	$3,217.0	$3,033.0	$2,529.0
Cost of Goods Sold (COGS)	$38,082.0	$37,628.0	$36,186.0
R&D Expense	$1,220.0	$1,206.0	$1,051.0

Source: Lockheed Martin Annual Report [22]

Table 16

PepsiCo.			
(all figures in $MM)	2008	2007	2006
Revenue	$43,251.0	$39,474.0	$35,137.0
Net Income	$5,142.0	$5,658.0	$5,642.0
Cost of Goods Sold (COGS)	$20,351.0	$18,038.0	$15,762.0
R&D Expense	$388.0	$364.0	$282.0

Source: PepsiCo. Annual Report [29]

Table 17

United States Steel Corp.			
(all figures in $MM)	2008	2007	2006
Revenue	$22,466.0	$15,701.0	$14,752.0
Net Income	$2,112.0	$879.0	$1,374.0
Cost of Goods Sold (COGS)	$19,723.0	$14,633.0	$12,968.0
R&D Expense	$625.0	$589.0	$604.0

Source: U.S. Steel Annual Report [36]

Table 18

Company Name	R&D Expense as % of Revenue		
	2008	2007	2006
Goodyear	1.88%	1.89%	1.82%
International Business Machines	6.12%	6.23%	6.68%
General Motors	5.38%	4.51%	2.93%
The Ford Motor Company	4.97%	4.35%	4.50%
Kellogg Company	1.41%	1.52%	1.75%
Apple, Inc.	3.41%	3.26%	3.69%
Nike Inc.	1.00%	1.00%	1.00%
Lockheed Martin Corporation	2.86%	2.88%	2.65%
PepsiCo.	0.90%	0.92%	0.80%
United States Steel Corp.	2.78%	3.75%	4.09%
Average	3.07%	3.03%	2.99%
Std Dev	1.87%	1.73%	1.81%

Figure 2

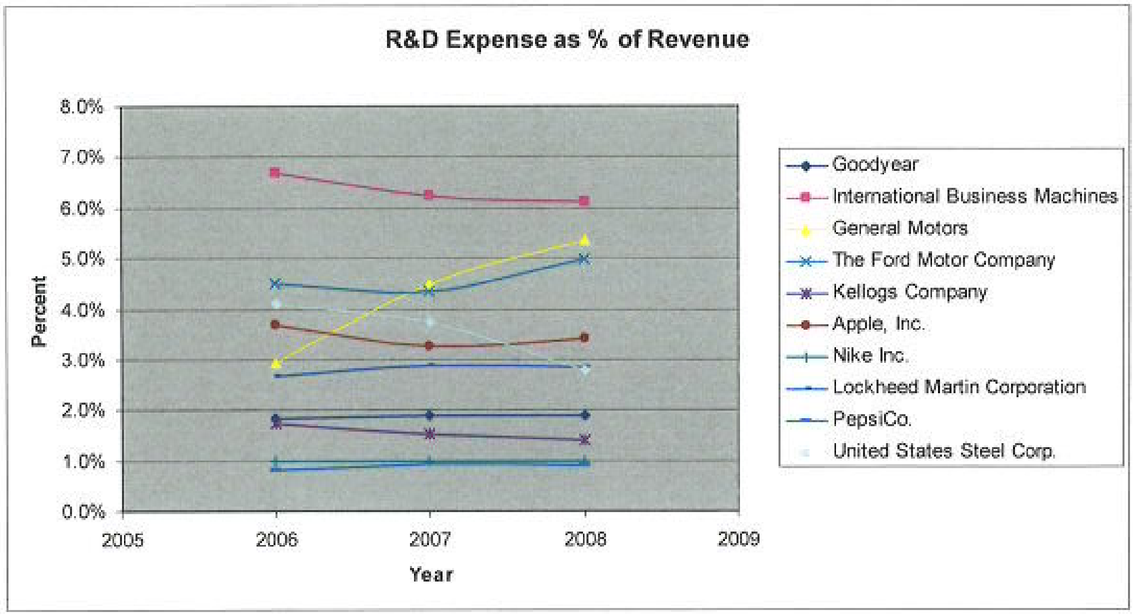


Figure 3

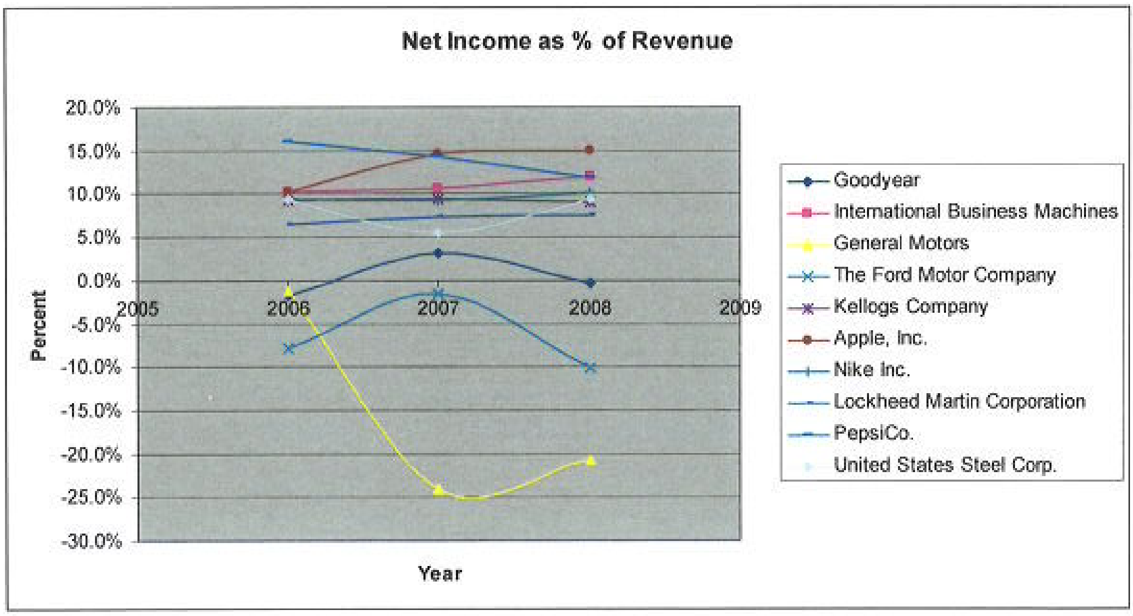
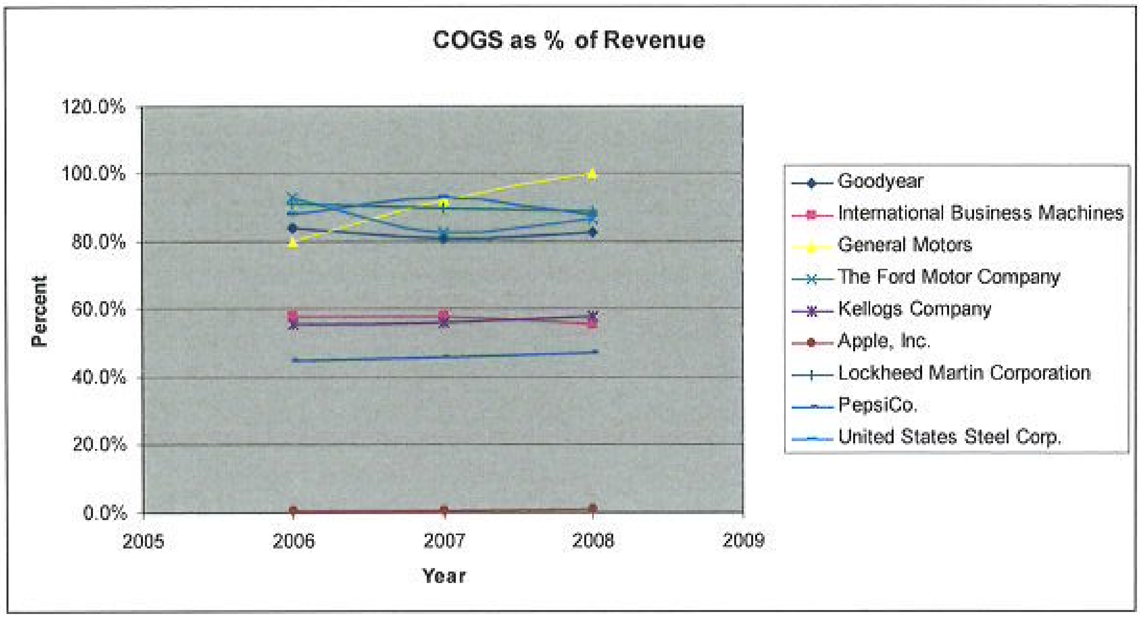


Figure 4

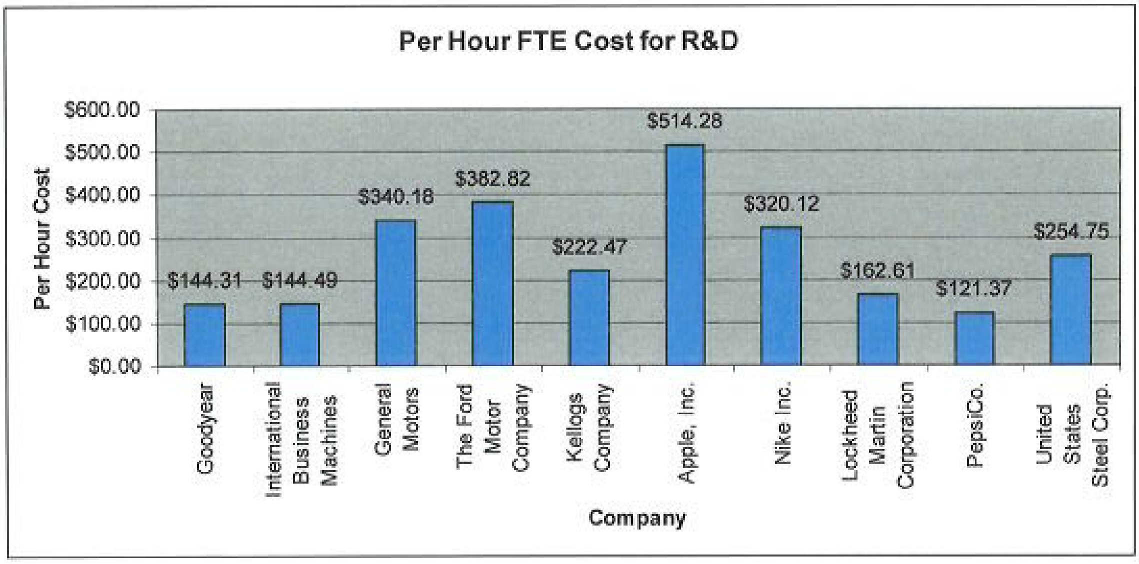

COGS as % of Revenue
120.0%
100.0%
80.0%
60.0%
40.0%
20.0%
0.0%
Percent
2005
2006
2007
2008
2009
Year
Goodyear
International Business Machines
General Motors
The Ford Motor Company
Kellogs Company
Apple, Inc.
Lockheed Martin Corporation
PepsiCo.
United States Steel Corp.

Appendix c – Full Time Equivalent (FTE) Calculation based on Financial Statements

Table 19

ompany Name	# Employees in 2008	R&D Expense for 2008	% Revenue Spent on R&D	# FTE's in R&D based on Revenue	$$ in 2008 for 1 FTE	# Hours for 1 FTE	Per Hour Cost for 1 FTE
Goodyear	75000	$366,000,000.0	1.88%	1409	$259,758.69	1800	$144.31
nternational Business lachines	398455	$6,337,000,000.0	6.12%	24366	$260,075.52	1800	$144.49
General Motors	243000	$8,000,000,000.0	5.38%	13065	$612,323.00	1800	$340.18
he Ford Motor Company	213000	$7,300,000,000.0	4.97%	10594	$689,069.28	1800	$382.82
ellogg Company	32000	$181,000,000.0	1.41%	452	$400,442.48	1800	$222.47
pple, Inc.	35100	$1,109,000,000.0	3.41%	1198	$925,709.52	1800	$514.28
Nike Inc.	32500	$187,270,000.0	1.00%	325	$576,215.38	1800	$320.12
ockheed Martin Corporation	146000	$1,220,000,000.0	2.86%	4168	$292,706.33	1800	$162.61
epsiCo.	198000	$388,000,000.0	0.90%	1776	$218,468.47	1800	$121.37
nited States Steel Corp.	49000	$625,000,000.0	2.78%	1363	$458,547.32	1800	$254.75
verage	142206	$2,571,327,000.0	3.07%	5872	$469,331.60	N/A	$260.74
td Dev	121481	$3,245,365,595.6	1.87%	7874	$229,767.00	N/A	$127.65
Max	398455	$8,000,000,000.0	6.12%	24366	$925,709.52	1800	$514.28
Vho's Max?	IBM	GM	IBM	IBM	Apple	N/A	Apple
Min	32000	$181,000,000.00	0.90%	325	$218,468.47	1800	$121.37
Who's Min?	Kellogg	Kellogg	PepsiCo	Nike	PepsiCo	N/A	PepsiCo

Figure 5



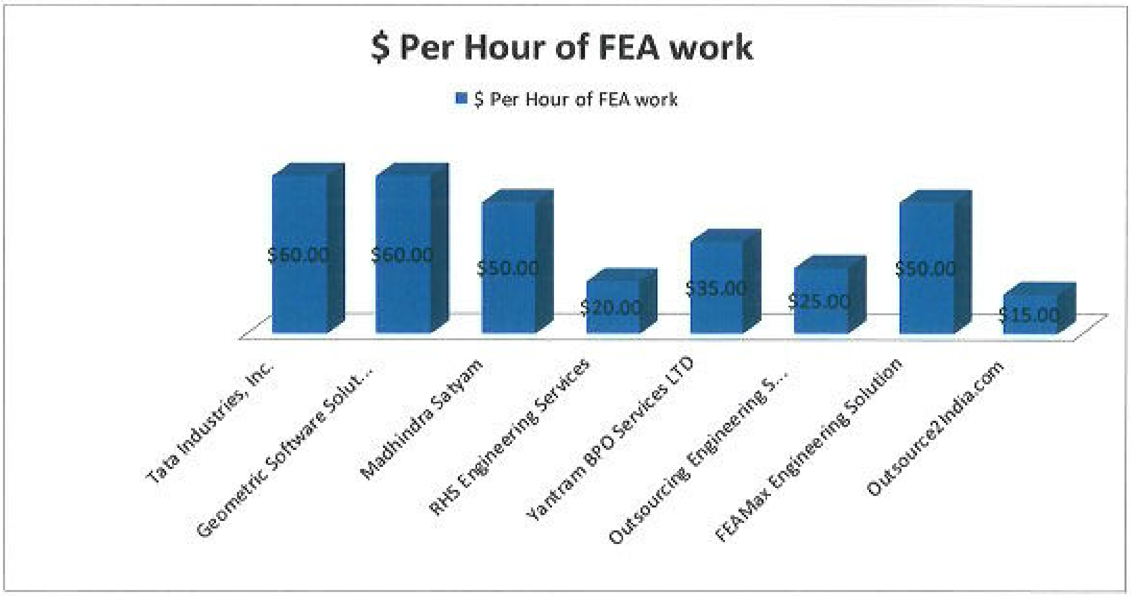
Per Hour FTE Cost for R&D
Per Hour Cost
$600.00
$500.00
$400.00
$300.00
$200.00
$100.00
$0.00
$144.31
$144.49
$340.18
$382.82
$222.47
$514.28
$320.12
$162.61
$121.37
$254.75
Goodyear
International Business Machines
General Motors
The Ford Motor Company
Kellogs Company
Apple, Inc.
Nike Inc.
Lockheed Martin Corporation
PepsiCo.
United States Steel Corp.
Company

Appendix d – Outsourcing Vendor Quotes

Table 20

Outsourcing Vendor	$ Per Hour of FEA work	Source
Tata Consultancy Services	$60.00	The Goodyear Tire & Rubber Company
Geometric Software Solutions	$60.00	The Goodyear Tire & Rubber Company
Mahindra Satyam	$50.00	The Goodyear Tire & Rubber Company
RHS Engineering Services	$20.00	http://www.rhs-services.com/Services.htm [32]
Yantram BPO Services LTD	$35.00	http://architectural-design.outsourcing-services-india.com/price.php [31]
Outsourcing Engineering Services	$25.00	http://www.outsourcingengineeringservices.com/ [28]
FEAMax Engineering Solution	$50.00	feamax.com [9]
Outsource2India.com	$15.00	outsource2india.com [27]
Average	$39.38	
Std Dev	$18.02	
High -- Tata, Geometric	$60.00	
Low -- Outsource2India.com	$15.00	

Figure 6



Appendix e – Outsource/Insource Comparison for Average Tire Project 1

Table 21

Average Tire Project 1, Outsourced and Managed by Inhouse Employees					
Activity	Inhouse Activity or Outsourced Activity?	# Hours	Average Inhouse FTE Rate	Average Rate Outsource	$ Cost @ Average FTE Rate
communication of geometric data from product design	In	3	$260.74	$39.38	$782.22
define material properties	Out	1	$260.74	$39.38	$39.38
meshing	Out	5	$260.74	$39.38	$196.88
define BC's, LC's of road, hub, and tire/vehicle weight	Out	5	$260.74	$39.38	$196.88
Management Check Conference Call for BC's and LC's	Out	3	$260.74	$39.38	$118.13
Management Check Conference Call for BC's and LC's	In	3	$260.74	$39.38	$782.22
Run Solver	Out	5	$260.74	$39.38	$196.88
Troubleshoot Solver Run	Out	4	$260.74	$39.38	$157.50
Post Process	Out	4	$260.74	$39.38	$157.50
Format & Check in Results	Out	4	$260.74	$39.38	$157.50
Inhouse post processing check	In	2	$260.74	$39.38	$521.48
Inhouse communication of Results to product design	In	2	$260.74	$39.38	$521.48
Cost for IT ****	In	16	$260.74	$39.38	$4,171.84
Total		41			$7,999.86
Total w/o IT costs					$3,828.02
Equivalent Per Hour Cost					$195.12
Equivalent Per Hour Cost w/o IT					$93.37
****This attempts to include large capital expenditures for computer hardware & software to run FEA solver					

Table 22

Average Project Tire 1, Done by Inhouse Employees					
Activity	Inhouse Activity or Outsourced Activity?	# Hours	Average Inhouse FTE Rate	Average Rate Outsource	$ Cost @ Average FTE Rate
communication of geometric data from product design	In	1	$260.74	$39.38	$260.74
define material properties	In	1	$260.74	$39.38	$260.74
meshing	In	5	$260.74	$39.38	$1,303.70
define BC's, LC's of road, hub, and tire/vehicle weight	In	3	$260.74	$39.38	$782.22
Management Check Conference Call for BC's and LC's	N/A		$260.74	$39.38	$0.00
Management Check Conference Call for BC's and LC's	In	1	$260.74	$39.38	$260.74
Run Solver	In	5	$260.74	$39.38	$1,303.70
Troubleshoot Solver Run	In	2	$260.74	$39.38	$521.48
Post Process	In	4	$260.74	$39.38	$1,042.96
Format & Check in Results	N/A		$260.74	$39.38	$0.00
Inhouse post processing check	N/A		$260.74	$39.38	$0.00
Inhouse communication of Results to product design	In	2	$260.74	$39.38	$521.48
Cost for IT ****	N/A		$260.74	$39.38	$0.00
Total		24			$6,257.75
Equivalent Per Hour Cost					$260.74