

Project Description

Part 1: Identification and Significance of the Innovation

The key innovation in this research is the establishment of a methodology for capturing manufacturing data to calculate Overall Throughput Effectiveness (OTE) and Activity Based Cost (ABC) in real-time for presentation over the web. These remote monitoring and presentation capabilities are being developed by eSourceWorld.com (eSourceWorld). The capability to remotely monitor and present real-time OTE and cost data will become an integral part of eSourceWorld's Manufacturing Activity-Based Sourcing and Control (MASC) system that will give manufacturing managers any-time, any-where access to critical information.

Three of the most important activities for a manufacturing manager are performance monitoring, process improvement and accurately determining production cost. All of these activities require a well defined methodology if the manufacturing manager is to make the correct decisions in areas such as pricing, outsourcing, capacity, quality control and areas for continuous improvement. A poorly defined model and incorrect analysis can lead to the failure of the manufacturing enterprise.

During the last two decades, attempts have been made to model, analyze, and design different aspects of manufacturing systems. Major modeling methods reported in the literature include:

- Graph with Results and Actions Interrelated (GRAI): based upon a conceptual reference model which uses two graphical tools and a structured approach (Carrie and Macintosh 1997, Chen et al. 1997, Doumeingts 1985)
- IDEFO: a function modeling language consisting of a hierarchy of diagrams, text, and glossary (Cheng-Leong et al. 1999, Ang 1999, Colquhoun et al. 1993).
- Structured Analysis and Design Technique (SADT): uses a number of graphical tools including diagrams, actigrams, datagrams, node lists and data dictionaries (Santarek and Buseif, 1998, Zaytoon et al. 1994, Down et al. 1988).
- Structured Systems Analysis and Design Method (SSADM): provides interfaces between the method procedure and techniques (Toh 1999, Ashworth 1988).

In addition to these formalized modeling methods, a number of other tools were also used in manufacturing systems modeling including Petri nets (Zimmermann and Hommel, 1999), object-oriented methods (Wong et al. 1999) and EXPRESS diagrams (Giachetti, 1999). These modeling methods are no more than static graphical representations and are not well defined. Therefore, the resulting models are open to misinterpretation and inconsistencies (Al-Ahmari and Ridgway, 1999).

The fact that the current modeling techniques result in ambiguous models has the additional consequence that *no well defined quantitative methods exist to compute the overall throughput effectiveness for a production line or factory* (Vernadat 1996). Recent publications by Scott (Scott and Pisa, 1998, Scott D. 1999) recognize and analyze the need for a coherent systematic methodology for productivity measurement and analysis at the factory level. This deficiency *makes it exceedingly difficult to monitor or optimize overall system performance*. The absence of an accurate model for a manufacturing process or factory *also makes it very difficult to determine the true cost of producing a product*.

Within the last three years promising research has been done at the University of Toledo to correctly and clearly model manufacturing systems and to accurately calculate the overall performance of the manufacturing systems (Su, 2001; Al-Abdulrazzak, 2001; Huang, 2001a and 2001b). The goal of the proposed research is to transfer that technology from the University of Toledo and to incorporate the technology into the MASC system that has been developed by eSourceWorld. Additional research will also be conducted to fully develop and extend the work done by the researchers at The University of Toledo that permits calculation of overall throughput effectiveness and activity based cost.

In the proposed methodology, the manufacturing system is modeled as a combination of a number of building blocks. The building block of a manufacturing system is a unit production process (UPP), rigorously defined as shown in Figure 1. The architectural combinations of UPPs, based on Burbidge's classification methodology (Burbidge 1994, 1992, 1990), are (1) series, (2) parallel, (3) assembly, and (4) expansion. A unit factory (UF) can always be decomposed into these basic architectural combinations. Productivity metrics for the UF, including OTE and system cycle time effectiveness (CTE_F), can thus be derived based on overall equipment effectiveness (OEE) of individual UPPs. Details of the derivation can be found in Su, 2001. In addition, an Activity Based Cost (ABC) methodology will be used to calculate manufacturing costs.

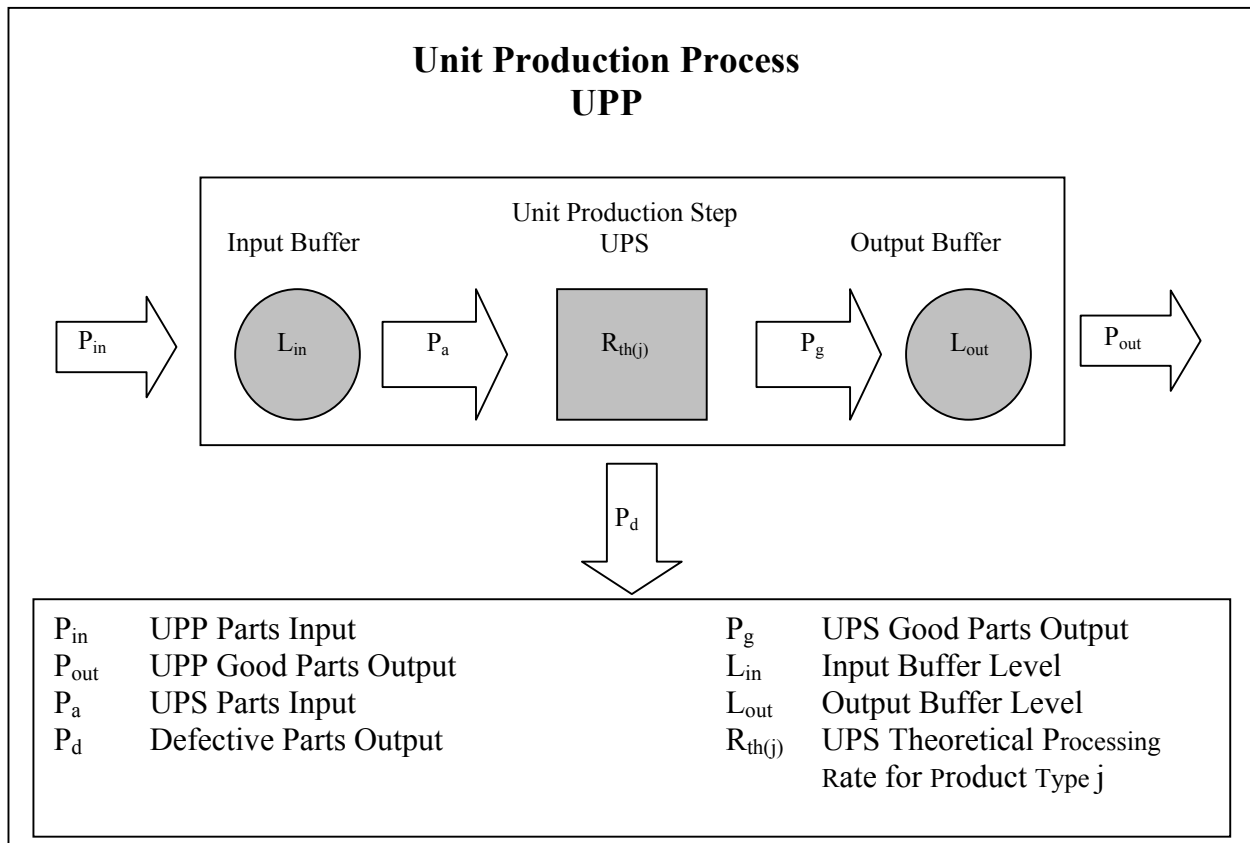


Figure 1. Definition of a Unit Production Process (UPP)

Once OTE and ABC can be determined, optimization schemes can then be developed and the system can be validated. To validate the research, a system will be modeled that is currently producing parts at National Composite Center. The composite industry was chosen to demonstrate and validate the research because it is rapidly expanding and is also a fairly young industry. This provides an expanding market for the proposed research and also is an industry where there are few analytical production tools available to manufacturers. Applying a rigorous set of production metrics and methodology will assist moving the industry from an “art” base to a science base.

The significance of the proposed research is tremendous. The basic techniques and analysis will be applicable to all manufacturers regardless of their product. Manufacturers will be able to reduce costs by effective monitoring of operation and optimization. The composites industry will be immediately impacted because of the involvement of the National Composites Center (NCC) in the validation process. The review of the proposed system and research results by the trustees and 51 members of NCC (including Boeing, BP Amoco, Delphi Automotive Systems, GE Aircraft Engine, Honeywell, Owens Corning, and a number of composite manufacturers) will also assist eSourceWorld in producing a system with the greatest commercial appeal. Also preliminary application of previous research by the University of Toledo in the flat glass industry has demonstrated considerable savings can be obtained even using a small subset of the techniques being proposed. This indicates that the chances for commercial viability are high.

The proposed research is an excellent project to be considered under the NSF topic of Advanced Materials & Manufacturing Systems and subtopic Enterprise Systems (C) because the proposed system is targeted at improving manufacturing system operation and design through a novel approach to modeling and analysis. The proposed research touches on all three areas of Enterprise Systems but is ideally suited to Productions Systems (2) because it is targeted at cost and performance analysis and will be included in an existing supply chain management system. The research also touches on the other areas, of Operation Systems and Enterprise Modeling because of the research in modeling, analysis, optimization, operation, simulation, and the interaction of people with the web based interface. Additionally, the proposed research also addresses advanced materials by modeling manufacturing processes in the composites industry.

Part 2: Phase I Technical Objectives

There are three technical objectives in the proposed research all relating to acquiring, processing and presenting information to manufacturing management so they may effectively manage and succeed in the global market place. The three objectives are to provide manufacturing management:

1. A measure of total productivity of a manufacturing line or factory as reflected in the Overall Throughput Effectiveness (OTE);
2. A measure of total cost of producing a product, based on an Activity Based Cost (ABC) framework;
3. A web-based methodology to improve factory performance and to develop new production line designs.

Part 3: Phase I Research Plan

The research plan for each of the three technical objectives is documented in the sections that follow. Each section contains a brief overview of the technical background followed by a description of the tasks to be performed.

3.1 Research Approach To Measure and Model Factory Level Productivity

The Overall Equipment Effectiveness (OEE) concept and metric introduced as part of the Total Productive Maintenance or TPM paradigm (Nakajima, 1988) has provided a quantitative metric which is becoming increasingly popular and widely used in a variety of industries for measuring the productivity of an individual production component (equipment, machine, tool, process, etc.) in a factory. The semiconductor industry, for example, is heavily relying on OEE because of an increasing concern over the recovery within 5 years of facility capital investment in wafer fabrication plants (Ames, 1995; Konopka, 1996; Leachman, 1997). The conventional or rate-based OEE metric measures the true productivity of an individual production component, modeled in this proposal in Figure 1 as a Unit Production Process (UPP), by quantifying the “six big losses” – 1) Breakdown Losses, 2) Setup and Adjustment Losses, 3) Idling and Minor Stoppages, 4) Reduced Speed Losses, 5) Quality defects and rework, and 6) Startup Losses. The conventional formula for OEE can be defined as,

$$\text{Conventional } OEE = A_{eff} * P_{eff} * Q_{eff} \leq 1 \quad (1)$$

where

A_{eff} = Availability Efficiency,
 P_{eff} = Performance Efficiency, and
 Q_{eff} = Quality Efficiency.

In Equation (1), $A_{eff} (\leq 1)$ captures the deleterious effects due to breakdowns, setups and adjustments, $P_{eff} (\leq 1)$ captures the losses due to reduced speed, idling and minor stoppages, and $Q_{eff} (\leq 1)$ captures the losses due to defects, rework and yield. However, quantitative OEE analysis only addresses productivity behavior of individual equipment, and gains made in OEE, while important and ongoing, are insufficient for maximizing overall system performance.

Scott (Scott, 1999; Scott and Pisa 1998) recognized the lack of a comprehensive theory for calculating the overall effectiveness or productivity of the manufacturing system or factory, based on the OEE factors of each of the UPPs. He correctly pointed out the need for a coherent, systematic methodology for measurement and analysis of factory level productivity as a guide to high performance, well-integrated manufacturing systems.

During collaboration since 1997 with the flat glass industry (Pilkington N.A.) under NSF and Pilkington funding, and more recently in collaboration with eSourceWorld beginning in 2000, the University of Toledo has conducted significant research on productivity improvement and the measurement and quantitative analysis of overall performance at both equipment and factory levels. The research results (Su et al., 2001; Huang et al., 2001a and 2001b; Al-Abdulrazzak, 2001; Wang et al., 2000; Dismukes, 1999a and 1999b; Chandrasekaran, 1999) have lead to the recent formation of the Center for Manufacturing Value Chain Science (CMVCS) at The University of Toledo. These results provide a sound foundation for a further improved, innovative approach proposed in this task to measure and model factory level productivity for a generic factory.

Task 3.1.1 Identification of the Four Basic UPP Combinations and Definition of Overall Throughput Effectiveness For a Generic Factory

A manufacturing system/factory is usually made up of one or more principal types of manufacturing system architectures, depending on industry type and which manufacturing stages are considered. By extending Burbidge's conceptual methodology (Burbidge 1994, 1992, 1990), we propose that all manufacturing systems can be factored into four basic "types" of unique UPP combinations or sub-systems, namely, "series", "parallel", "assembly", "expansion or dis-assembly", which will serve as the building blocks to construct any generic, complex manufacturing system.

By extending the expression of unit-based OEE, which has been proposed and developed at the University of Toledo (Su et al., 2001; Al-Abdulrazzak, 2001) and found more robust than time-based OEE (Leachman, 1997) as a basis for factory level metrics development, the overall throughput effectiveness (OTE) during the period of T_T can be defined as

$$OTE = \frac{\text{good product output (units) from factory}}{\text{theoretical actual product output (units) from factory in total time}} = \frac{P_{g(F)}}{P_{a(F)}^{(th)}} \quad (2)$$

This OTE metric measures the true productivity of system or factory, because it is based on a correct calculation of average theoretical processing rate of the factory. In Equation (2), $P_{g(F)}$ is the actual good product output (units) of a system/factory during the period of T_T . $P_{a(F)}^{(th)}$ is the theoretical total product output at the system/factory level in total time T_T , given as

$$P_{a(F)}^{(th)} = (R_{avg(F)}^{(th)})(T_T) \quad (3)$$

where $R_{avg(F)}^{(th)}$ is defined as the average theoretical processing rate for total product output from the system/factory, which is a function of the system interconnectivity (material flow).

Task 3.1.2 Measurement and Modeling of Factory Level Productivity

The underlying concept for this modeling approach is that based on the theory of material flow conservation and facility layout of manufacturing processes, the overall throughput effectiveness, OTE, of each of these four basic UPP combinations can be uniquely calculated from production data. Hence the system/factory level overall throughput effectiveness, OTE_F , can therefore be calculated in a similar manner by combining the OTE of the basic UPP combinations making up the complex system/factory.

To be able to use the four basic UPP combinations as building blocks, the OTE and the average theoretical processing rate ($R_{avg(F)}^{(th)}$) of each of these four basic UPP combinations must be uniquely calculated. The method to calculate the OTE for each of the four basic UPP combinations is graphically illustrated in Figure 2, which is simplified for presentation in this proposal without disclosure of intellectual property (Dismukes et al., 2000). Specifically, each of four basic UPP combinations is transformed into an equivalent sub-system by satisfying the condition: the OTE and the average theoretical processing rate of the equivalent sub-system are equal to the OTE and the average theoretical processing rate of the corresponding basic UPP combination respectively, i.e. $OTE_{(Equivalent)} = OTE$ and $R_{avg(Equivalent)}^{(th)} = R_{avg(F)}^{(th)}$.

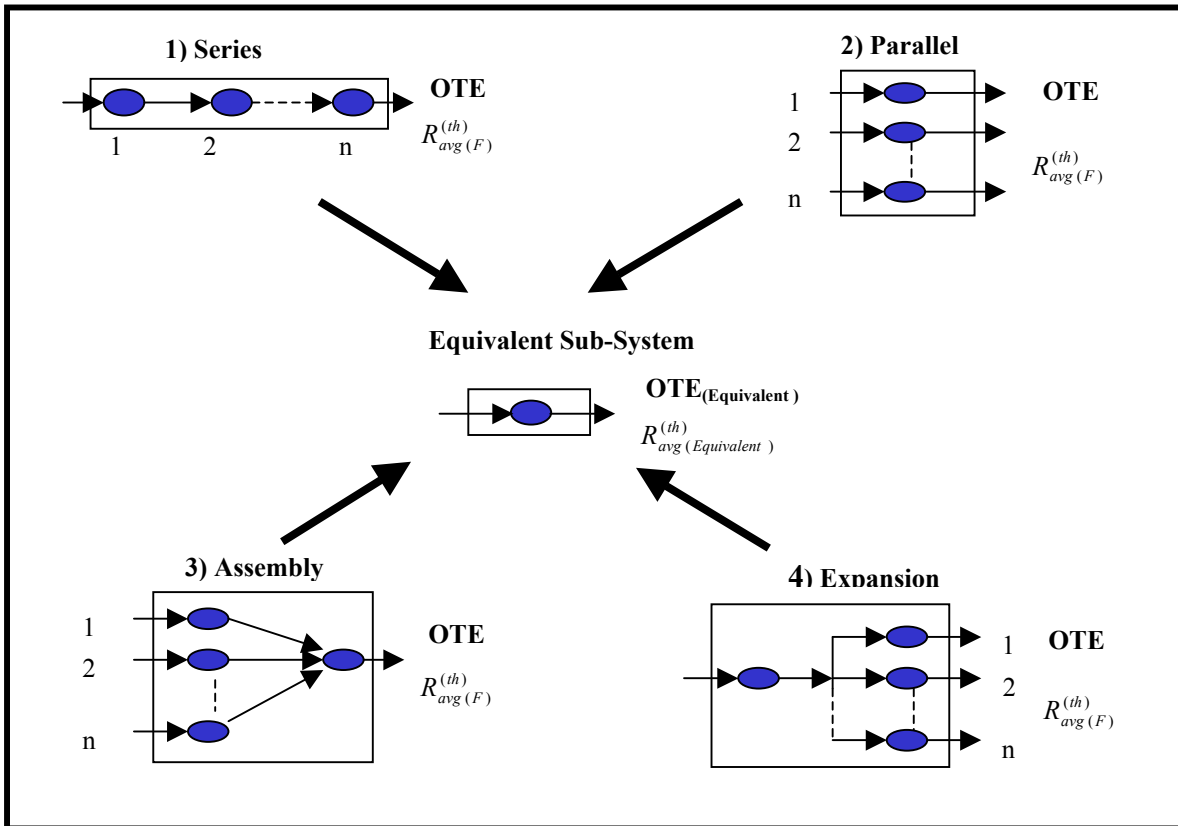


Figure 2. Equivalent sub-system for the four basic UPP combinations

For measurement of a complex manufacturing system or factory, the research approach is summarized by the following steps:

- 1) Decompose the complex manufacturing system or factory into a number of the four basic UPP combinations based on the UPPs in the system/factory, operation sequences, and system/factory layout.
- 2) Transform each of the basic UPP combinations identified in Step 1 into an equivalent sub-system based on the method described above.
- 3) Further transform the set of equivalent sub-systems into an equivalent system, which represents the complex system or factory, in similar manner as Step 2.

3.2 Methodology Development to Measure and Model True Product Cost

Traditional cost accounting (TCA) systems treat manufacturing cost as the sum of direct costs (i.e. labor and material) and indirect costs or overhead (i.e. the sum of all other factory and company costs). TCA systems provide a reasonably accurate product cost basis for organizations producing few products, with direct costs comprising the majority of total costs. However, TCA systems can lead to serious errors (e.g. + 200% to - 1000%) in calculated product cost (Lewis, 1993) for today's complex industrial organizations operating with significantly reduced direct labor, and with total direct costs less than total indirect costs. Such errors are particularly serious when they erroneously influence management decisions regarding product strategy and pricing. Consequently, activity based cost (ABC) systems have been increasingly adopted over the past

dozen years to calculate true product manufacturing cost by correct allocation of direct and indirect costs (Cokins et al., 1992; Cokins, 1996; Kaplan and Cooper, 1998; Spedding and Sun, 1999; Roztock, 2001). The ABC cost management system identifies the resources, and hence costs, consumed by each direct and indirect activity in the factory and the overall organization, and correctly allocates these costs to specific production processes and products via a cost driver matrix linking costs of activities to specific production processes and products.

In the following two tasks, a research approach is proposed to integrate ABC principles with the methodology described in Part 3.1 to model true product cost. This innovative approach has advantages over the current ABC systems used by most companies. First, the proposed innovative approach allows the cost of a product to be traced to the activities down to equipment level such as individual UPP according to the manufacturing process. Second, the proposed innovative approach links equipment and system productivity to the cost of a product.

Task 3.2.1 UPP and Factory ABC Framework

The approach to integrating the UPP concept, Figure 1, with ABC principles to determine true product cost is graphically illustrated in Figure 3. Each UPP in a system/factory is treated as a UPP activity center, which performs a set of specific activities such as set-up, machining, and engineering, depending on the function of the activity center. For example, if the function of a UPP activity center is CNC machining center, then the set of activities will be set-up, machining, or engineering. If the function of a UPP activity center is inspection station, then the set of activities will be set-up, inspecting, etc. Each UPP activity center consumes a portion of factory overhead resource costs. Similarly, each product manufactured in the system/factory consumes a portion of costs of a UPP activity center.

In the approach, the factory overhead resource costs and resource cost drivers will be identified. The factory overhead resource costs, which are divided into direct activity costs and indirect activity costs, as illustrated in Table 1 below, can be obtained easily from accounting and be calculated based on factory data for the time period, T_T . The difference between direct activity costs and indirect activity costs is that the direct activity costs are those factory overhead resource costs that are directly consumed by UPP activity centers. Note that as a basic framework, those costs listed under the direct activity and indirect activity costs are not fixed. Different companies and industries use varying versions fitting their preference of the different nature of manufacturing and other functions. We will develop a final “Framework” appropriate to the Composite industry during the research.

So the generic “Framework” we propose should be capable of adjustment to any company or industry based on our theoretical and experimental findings. The direct activity costs contributed to each UPP activity center are directly calculated based on the actual consumption of the activity center during the period, T_T . The indirect activity costs are then assigned to each activity center via resource cost drivers (indirect activity cost drivers) being identified. Next, the factory overhead resource costs are recast as activity center costs. Finally, the activity center cost drivers for each UPP activity center are determined to allocate the activity center costs to individual product according to the operation sequences of products processed during the period, T_T .

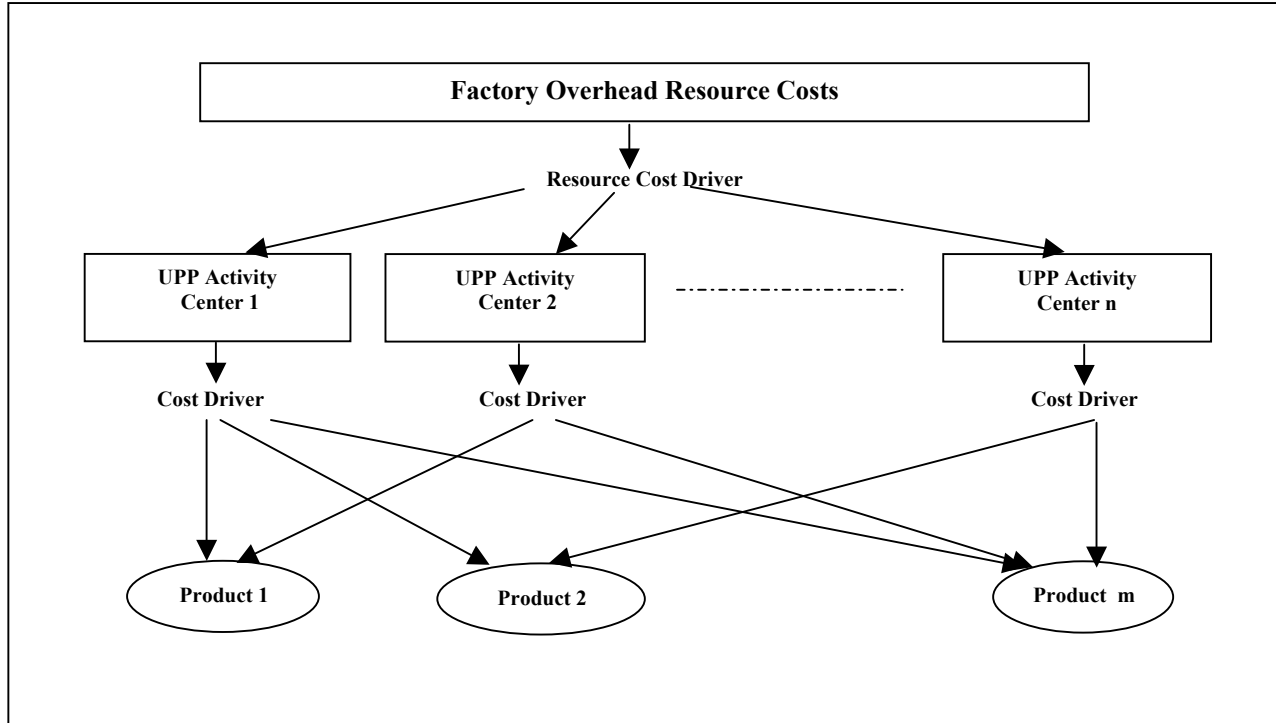


Figure 3. Factory ABC structure

Task 3.2.2 UPP and Factory ABC Model

In this task, a cost model to expressing the cost of a unit of good product on an ABC basis as a function of the equipment level productivity (OEE) of UPP (the activity center) will be developed. As mentioned in Task 3.2.1, the direct activity costs and indirect activity costs will be obtained from accounting. The cost of each direct activity cost component (DC_i) can be directly calculated based on factory data for the actual consumption of the UPP activity center during the time period, T_T . The cost of each indirect activity cost component initially will be estimated from quantities budgeted by the manufacturing organization on an appropriate time basis (e.g. daily or annually), and these costs will be updated to reflect actual data once these data become available. On the assumption that the resource cost drivers (indirect activity cost drivers) and the activity center cost drivers have been identified, the costs traced to each UPP activity center during the period, T_T can be determined as

$$ACC_i = \sum_j DC_{ij} + \sum_j ICD_{ij} \times IC_j$$

Where

ACC_i = total cost of UPP activity center i

DC_{ij} = the j th direct activity cost component contributed to UPP activity center i

IC_j = the j th indirect activity cost component

ICD_{ij} = indirect activity cost driver which allocates j th indirect activity cost component to UPP activity center i

Assume during the period, T_T , a batch of product type k is manufactured in a system/factory. The number of good product output is P_g and the number of actual product input is P_a . The operation sequence for this type of product is $OP = \{i | UPPs\}$, Thus, the total cost of a good product for the product type k during the period, T_T can be determined as

$$PC_k = \frac{DM_k \times P_a + \sum_{i \in OP} \sum_j ACC_{ij} \times ACD_{jk}}{P_g}$$

$$= \frac{DM_k}{Q_{eff}} + \frac{\sum_{i \in OP} \sum_j RACC_{ij} \times ACD_{jk}}{OEE_i \times R_{avg(i)}^{(th)}}$$

Where

PC_k = total cost of a good product for product type k

DM_k = direct material (raw material or semi-finished product) cost for product type k

Q_{eff} = quality efficiency (yield) of system/factory during the period, T_T

ACC_{ij} = the j th activity cost of UPP activity center i during the period, T_T ,

$$ACC_i = \sum_j ACC_{ij}$$

ACD_{jk} = activity center cost driver, which traces the j th activity cost to product type k

$$RACC_{ij} = \frac{ACC_{ij}}{T_T}$$

Table 1 ABC Framework For Factory Overhead Resource Costs

DIRECT ACTIVITY COSTS (DC _i)	INDIRECT ACTIVITY COSTS (IC _i)
Manufacturing	Marketing and Sales
Engineering	Advertising and Public Relations
Consumable Materials	Purchasing
Energy	Distribution, Shipping, Receiving, Storage
Utilities	Financial, Legal, and Insurance
Labor	General and Administrative (G&A)
Tooling	Depreciation
Inter-UPP Transport	Research and Development (R & D)
	Material Handling & Transportation
	Plant Engineering and Maintenance

3.3 Web-Based Methodology For Productivity and Cost Optimization

As discussed above in Part 1, recent literature and manufacturing experience indicate that existing approaches for measuring, analyzing and modeling factory level productivity and cost

based on throughput and utilization rate fall short of identifying problems and underlying opportunities for improvement and optimization. It is proposed to address this deficiency by further improvement and extension of recent techniques for manufacturing system productivity improvement (Al-Abdulrazzak, 2001; Huang et al., 2001a and 2001b) developed at The University of Toledo. The envisioned methodology and software tools will enable rapid sensitivity analysis for improvement and optimization of factory productivity and cost, and the development of new production line designs. Tools and services will be provided using a web-based portal service for “anywhere-anytime access”. The attendant transport and workflow architecture is illustrated in Figure 4.

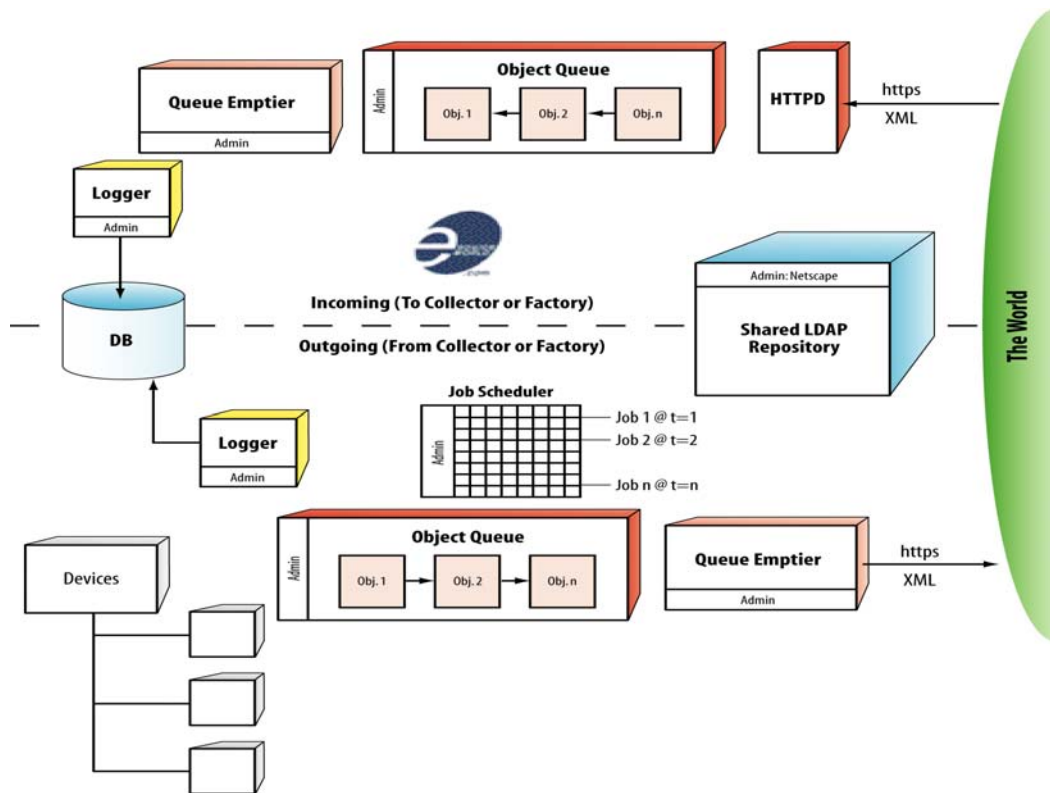


Figure 4. Transport and Workflow Architecture

The National Composite Center will participate by making a prototype composite manufacturing line available for evaluation, as well as coordinating interaction with a composite part manufacturer who will assess the use of the new methodology in transferring the composite technology from a prototype line to a full commercial production system.

Task 3.3.1 Methodology and Software Tool Development

A preliminary performance improvement methodology has been developed (Huang et al., 2001a). The methodology features (1) the use of a software tool for electronic flowcharting, with capability for data input and metrics output, and (2) the integration of productivity metrics with discrete event simulation (Huang et al., 2001b). The software tool will be further developed to (1) incorporate the generic algorithms and metrics for productivity and activity based cost as

proposed in Tasks 3.1 and Task 3.2 respectively, and (2) automatically generate simulation models as a basis for sensitivity analysis. The result will be rapid identification and assessment of performance improvement opportunities.

Task 3.3.2 Validation in a Pilot Composite Factory at National Composite Center

Experimental testing and validation of the methodology and software tools described in Task 3.3.1 will be conducted by applying them to a developmental production line that produces composite firefighter helmets at the National Composite Center (NCC), Kettering, OH. This pilot production line makes use of Owens Corning's patented Programmable Powdered Preform Process (P4) for the production of fire helmet shells with improved performance, appearance and economy compared to those currently produced based on woven mats and sheet molding compounds. The P4 process involves the use of male and female screens, a robotically actuated chopper gun, a consolidation device which compresses the chopped fibers to a predetermined loft, and a powder binder applied during the chopping operation. The P4 process sequence includes the following subtasks: a) fiberglass and binder deposition using a robotic chopper arm assembly, b) consolidation of the preform to a predetermined height followed by forced air heating to melt the binder, c) the solidification of the binder using ambient air and d) removal of the preform by lifting the top screen to facilitate release of the preform. The preforms are then processed in a heated steel mold with a gel-coat finish and by open mold deposition of a resin mixture. The result is a helmet with the high gloss of a painted helmet product, the improved scratch resistant finish of a gel coat and the high performance of a woven glass fiber reinforced plastic product all at the lowest finished weight possible. A preliminary flowchart of this model factory is illustrated in Figure 5 below.

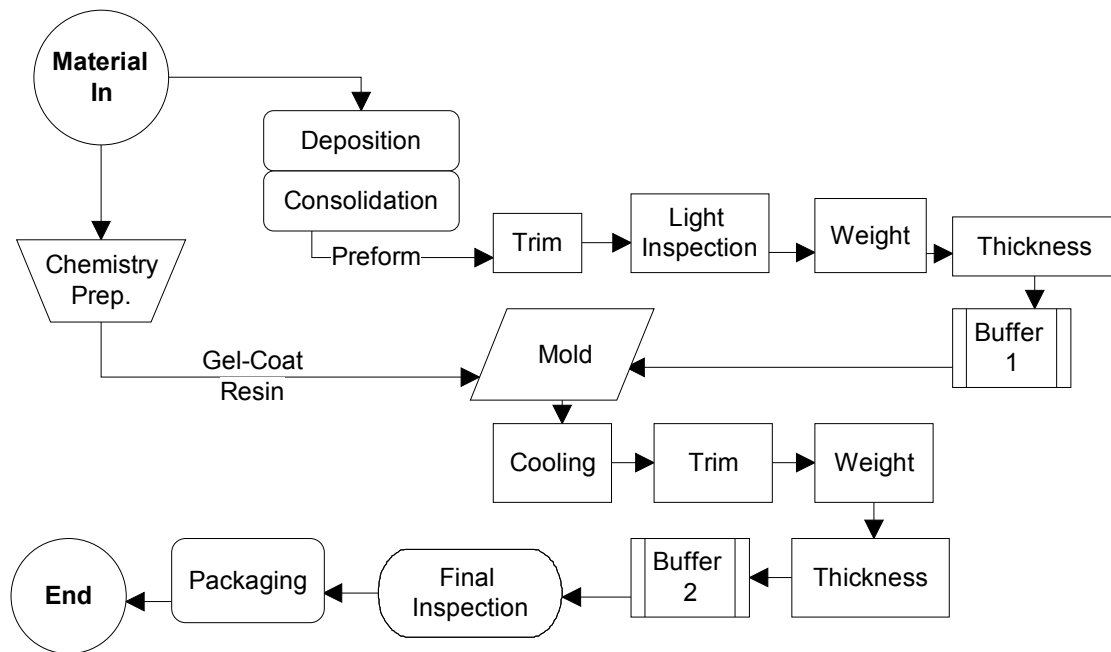


Figure 5. Schematic Flow Chart for the Pilot Factory for Composite Firefighter Hats

Based on the determination of the productivity (OEE) and activity based cost (ABC_U) for each UPP in this pilot factory, factory level productivity (OTE_F) and factory level activity based product cost (ABC_F) will be calculated based on productivity and cost data for the pilot factory supplied by NCC. The relations between OEE, ABC_U , OTE_F and ABC_F for the pilot composite factory, and the reliability of the electronic flowcharting and automated simulation capabilities will be analyzed as a basis for proceeding to Task 3.3.3.

Validity of the research methodology and results will be confirmed through peer review by the NCC Technical Steering Committee, made up of key NCC company members representing various companies in the composite value chain, including: fiber suppliers, resin suppliers, converters, molding tool and equipment suppliers, composite fabricators, original equipment manufacturers, and customers for composite products.

Task 3.3.3 Assessment of the Methodology for Optimization and Commercial Manufacturing System Design

The research team will work in collaboration with the NCC and a composite fabricator interested in evaluating the commercial feasibility of a larger scale commercial factory for producing the composite helmet. The purpose of the work will be to assess the use of the methodology and software tool developed in Task 3.3.1 for productivity and cost analysis of the various alternatives in moving to a full-scale commercial production system. The NCC Technical Steering Committee and the collaborating composite fabricator company will provide the scale up or transformation factors affecting both productivity and activity based cost. This group will also provide assessment, feedback, and recommendations regarding the validity and usefulness of the methodology as an aid in accelerating technology transfer to commercialization.

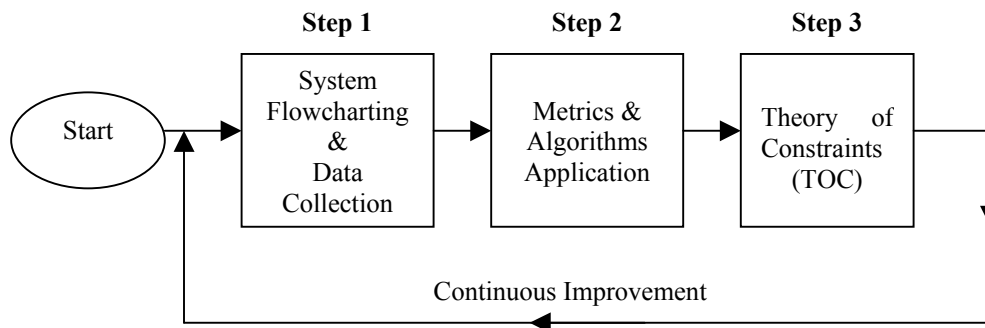


Figure 6. Optimization of Productivity and Cost (OPAC) Methodology

Figure 6 is an activity flow diagram representing the general steps comprising the system productivity improvement cycle which will be conducted as a basis for improving the pilot composite firefighter helmet production shown in Figure 5. Each step involves multiple sub-tasks. Step 1 develops a detailed understanding of the process activities exhibited in a flowchart of the manufacturing system architecture, which identifies the unit production processes (UPPs) and their interconnectivities with other UPPs in the factory. This step also includes establishing a mechanism for collecting and storing production data.

Step 2 applies the algorithms and metrics from Task 3.1 for OEE and OTE according to the model factory flowchart and data collected during the predetermined time intervals, to calculate the productivity of each UPP (OEE), each sub-system (OTE), and finally the whole system OTE_F . During this step, ABC costs will also be calculated for each UPP, each product, and the factory based on the approach outlined in Task 3.2.

Step 3 applies the Theory of Constraints (TOC) as an analytical tool to assess the current status of system productivity (e.g. bottleneck and constraint analysis) in addition to proposing solutions for enhancing overall system performance. In this step automated simulation will also be applied as a guide to sensitivity analysis for predicting productivity and activity based cost in a commercial scale factory. The concept encourages repeated improvement and optimization through a feedback cycle as shown in Figure 6.

If the methodology and software tools are proven to be useful in optimizing production and cost for the commercial system, it will mean that the new productivity and cost system can be used for optimization and design as well as process monitoring.

Part 4. Commercial Potential

Several manufacturing categories would benefit from eSourceWorld services. Among them are automotive and parts manufacturing, petrochemical refining, chemical processing, and plastics manufacturing. According to various government publications, there are 6,570 firms in these industries in Mexico, Canada and the United States that have 100+ employees. The breakdown of firms is summarized in the following table.

Industry Description	Number of firms With 100+ Employees
United States	4,612
Electronics	1,844
Automotive mfg. & parts	1,427
Petrochemical refining	240
Chemical processing	842
Plastics manufacturing	259
Canada	624
Electronics	149
Automotive mfg. & parts	105
Petrochemical refining	53
Chemical processing	121
Plastics manufacturing	197
Mexico	1,334
Electronics	336
Automotive mfg. & parts	327
Plastics manufacturing	670

Although these industries are identified as the most likely early adopters of this new technology, the true market opportunity encompasses all manufacturing operations throughout North America. According to the 1997 Economic Census, approximately 363,800 manufacturing establishments exist in the United States. Similarly, Mexico has 265,400

manufacturing establishments. Therefore, estimates made by targeting only the five industries above are definitely conservative in the long-term. We estimate the revenue potential from all industries to be over \$2Billion per year.

The commercial potential in the composites industry, which is the targeted industry for this STTR project, is referenced in the supplementary document, “Commercial Potential for a Web-Based Methodology in the Composite Industry”. The selection of this industry is extremely attractive because:

- 1) composites are an emerging technology, and
- 2) there is large growth potential in high volume market segments.

Part 5. Company Information and Management Team

The distribution of employees by category are given in Table 4.1

Category	Number of Employees
Technical Personnel	2
Administrative Personnel (including legal)	2
Management Personnel	1
Manufacturing Personnel (including sales)	2

Table 4.1 Employees by Category

The number of full time employees is 4 and the number of part time employees is 3. Future staffing plans are to hire 4.

The income by area is given in Table 4.2.

Revenue Area	Revenue
Sales - revenues from products and services	\$36,000
Licensing - revenues from licensing agreements with other organizations	
Contracts and Consulting	\$50,000
Other SBIR/STTR Grants or Contracts - revenue from grants or contracts from other Federal agencies	

Part 6. Consultants and Subawards/Subcontracts

The only subcontract under this proposal is to the University of Toledo (\$56,999) for research in the fundamental techniques and analytics for the three research objectives. Those objectives are: the development of performance measures, the development of costing, and the web-based methodology to improve factory performance and develop new manufacturing lines or factories. ESourceWorld will also be a participant in those three areas of research but with a focus on the real-time acquisition and display of data over the web.

National Composite Center (NCC), represented by Mr. Louis Luedtke (President and CEO) and Mr. Scott Reeve (Vice President Engineering), will participate on a consultant basis. ESourceWorld will fund NCC for this in the amount of \$3,000.

Part 7. Equivalent or Overlapping Proposals to other Federal Agencies

eSourceWorld has not submitted any proposals for the research described in this proposal to any other Federal Agencies.