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Cost Drivers of Manufacturing Overhead: A Cross-sectional Analysis of Automobile Component Manufacturing Plants*

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Abstract

This paper tested whether volume and complexity-driven support activity drivers are significant in explaining variation of overhead. Data used include cost and activity data for the 74 automobile component manufacturing plants. Each of volume and support activity variables showed significant marginal contribution to the explanation of overhead variation This result supports the assumptions of both traditional and ABC systems suggesting that both volume and support activity drivers are useful for cost allocation and cost management purposes Among the support activities, process balancing activities, purchasing control activities, and change activities showed significant positive effects on manufacturing overhead

The higher level of tests showed that selected structural complexity variables explain the variation of support activity drivers, especially process balancing, purchasing control and change activities This result partly supports the notion that structural production complexity drivers have significant influence on the level of support activities We may conclude that cost management should be considered from a strategic viewpoint as well as from an operation management viewpoint.

1. Introduction

Due to production automation, manufacturing overhead is

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increasing while direct labor costs are decreasing (Miller & Vollmann (1985)). This cost structure change has caused a new concern for the cost drivers of manufacturing overhead. Activity Based Costing (ABC) is one of many innovative cost management techniques dealing with the cost drivers of manufacturing overhead. ABC supporters assert that cost drivers of manufacturing overhead are complexity-related activities rather than volume-related measures (Cooper & Kaplan (1991)). While ABC is adopted by many world class companies (Cooper et al. (1992), and Brimson (1991)), empirical evidence is not sufficient to verify the assertions of ABC supporters (Banker, Potter, & Schroeder (1995), and Foster & Gupta (1990)).

This paper attempts to provide additional empirical evidence regarding the cost drivers of manufacturing overhead. Previous cost driver studies focused mainly on the direct effect of various cost drivers on manufacturing overhead. This paper, however, classified the previous cost drivers into two different levels and included the analysis of inter-relationships between different levels of cost drivers.

The data collected for this analysis consists of 74 plants of the automobile component industry which supply their products to one major automobile manufacturer. By limiting the scope of the study to a homogeneous industry, we are able to control for the effects of the industry.

Empirical results of this study supported that complexity-related activity variables indeed drive the cost of overhead. This is consistent with the assertions of ABC supporters. Moreover volume-related activity variables also positively influence overhead. This result partly defends the traditional practice of allocating overhead using volume based drivers. We can conclude that volume-related and complexity-related variables are indeed cost drivers of overhead.

Additional tests showed that structural complexity variables partly explain the variation of supporting activity variables, especially the variables that were identified as significant in explaining overhead variation in the above analysis.

2. Prior Literature

Foster and Gupta (1990) were among the first researchers on the area of cost driver analysis. Using 37 electronic plants they tested whether volume, complexity, and efficiency variables actually change the level of overhead. Results supported the notion that volume-related variables are still the most important variable explaining the overhead changes. Banker, Potter, and Schroeder (1993) analyzed 32 automobile, machinery and electronic component plants to examine the impact of volume and supporting activity variables on overhead. To operationalize supporting variables, they used Miller and Vollmann's framework (1985). In contrast to the results of the previous study, their results supported that complexity-related activity variables are significant explanatory variables of overhead changes. Anderson (1995) recently tested the effect of product mix heterogeneity on overhead using the time series data of three textile plants. Empirical results of this study demonstrated the effect of product mix heterogeneity on overhead.

Cost driver studies are not limited to the manufacturing industry. Banker and Johnston (1993) collected the archival panel data of the U.S. airline industry and analyzed the effect of volume and operation based variables on overhead. They found that both variables are significant explanatory variables of overhead changes. Noreen and Solderstrom (1994) used hospital activity data of the state of Washington and investigated whether a strict proportionality assumption holds in the relationship between activity variables and activity costs.

In contrast to the previous cost driver studies, Ittner and MacDuffie (1995) tested the effect of structural and executional drivers on the manufacturing overhead. Sixty-two worldwide auto assembly plants were used. They showed that structural variables have a significant impact on overhead while the executional variables did not show any meaningful impact.

Conceptual framework used in a cost driver study varies depending on the focus of the study. As described earlier, we could use Cooper's framework for cost driver classification (1990) or Miller and Vollmann's framewok (1985). Although both studies tried to identify the various cost drivers hidden in the previous studies, their classification methods are different Shank and Govindarajan (1994) suggested another well-known cost driver classification, which contains two typical categories such as structural and executional cost drivers.

Based on these previous studies, we can identify three levels of cost drivers (Ahn (1998)). Level 1 drivers are structural cost drivers which influence Level 2 cost drivers such as volume and complexity cost drivers. Level 3 cost drivers are activity cost drivers which are supposedly affected by Level 2 cost drivers. These Level 3 cost drivers, however, affects overhead cost. A clear-cut rule does not exist for classifying cost drivers into certain categories. For example, product complexity can be classified as a structural cost driver or a complexity-related driver depending on the specific measures used. If complexity is measured at a very detailed component level, then it could be classified as a complexity (Level 2) driver. If the product complexity is measured at an aggregate level such as a number of product lines or product groups, however, then it could be classified as a structural cost driver.

Hays and Clark (1985) attribute production complexity to variety of technology, flow patterns, and production stages in place at the factory. Riley (1987) argued that the extent of vertical integration, demand uncertainty, and work force policy may influence production complexity. Tatikonda and Tatikonda (1993) also recognized the hierarchy in the cost driver structure — the production complexity of plants will cause activities which will in turn drive overheads.

Foster and Gupta (1990) classified cost drivers into volume, complexity, and efficiency. As shown in Figure 1, Banker and Potter (1994) recognized the hierarchy in cost drivers and categorized cost drivers into volume drivers, production complexity drivers and support activity drivers which are influenced by volume and production complexity drivers Note that activity is a basic unit of analysis such as product inspection activity and component assembly activity. This paper used Banker and Potter's classification of cost drivers.

This framework assumes a hierarchy in cost drivers As shown in figure 1, production complexity is hypothesized to generate various kinds of support activities which, in turn, will increase

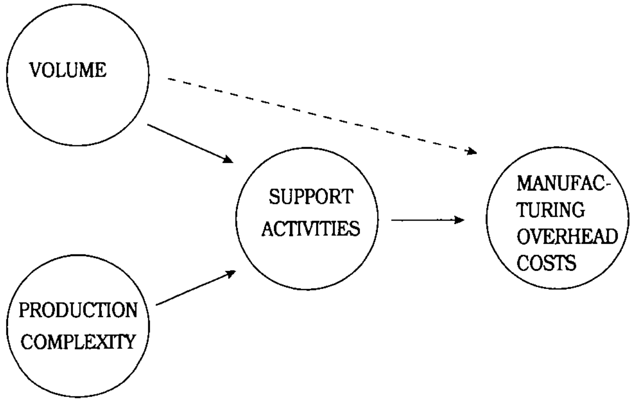

Figure 1. Cost Drivers of Overhead

manufacturing overhead. Volume may change manufacturing overhead either directly or indirectly through support activities as represented by the dotted line.

3. Research Method

3.1. Data

In this study, we report on the results of a cross-sectional analysis of auto-component plants where we can observe considerable variation in operating practices. When we use a time-series analysis, we may be able to control for variation due to production technology, cost function, and administrative differences (Banker and Potter (1994)). But it may provide very little variation in production complexity and support activities. In order to examine the impact of potential cost driver variables on overhead, we need variation in independent variables. While cross-sectional analysis allows us to have some variation in cost driver variables, we should accept the possibility of differences in production technologies, cost relationships and the number of support and administrative activities among plants used in the study.

This study used the data of 74 automobile component manufacturing plants. Unlike previous studies that dealt with multiple industries (Banker, Potter, and Schroeder (1993), Banker and Potter (1994)) the samples used are confined to a single industry. This might facilitate the control for cost behavior differences among industries (Raffi and Swamidas (1987)).

The first data collection attempt was made by sending the questionnaires to automobile component manufacturing firms listed in the directory of automobile component manufacturing industry. Since the items in questionnaire asked for detailed data, the response rate was extremely low. The second attempt was to contact a major automobile assembly company and collect data from supplier firms of that company. Response rate was relatively high.

Survey questionnaire items were similar to the ones used in Banker and Potter (1994) although revisions were made to fit the Korean environment.[1] Although sample firms used in the study are supplier firms of one automobile assembly company, they produce a wide variety of products ranging from antennas to transmission.

3.2. Measurement of Support Activities

As shown in Figure 1, while volume and production complexity are supposed to affect support activities, support activities are hypothesized to influence manufacturing overhead directly. Therefore production complexity may influence manufacturing overhead indirectly by changing the level of support activities.

Miller and Vollmann (1985) categorized support activities into four classes of transactions from an operation management viewpoint. These transactions include logistics transactions, balancing transactions, quality transactions, and change transactions. Similarly Schroeder's classification (1993) includes the activities related with the process flow design, purchasing and materials control, process balancing, quality and engineering change. This paper followed the Schroeder's approach.

Process balancing activities deal with the control and

1) For example, the manufacturing cost classification is direct material, direct labor, and overhead in the U S In Korea, however, direct and indirect material costs are not differentiated Therefore we specifically mentioned this differentiation in classification and asked the respondents to classify cost items into direct materials, direct labor, and manufacturing overhead

maintenance of production throughout the plant. The coordination of work orders, batches, labor, and capital require planning and scheduling activities, which in turn demand personnel to deal with the bills of materials, production orders, and equipment scheduling. Failure to balance processes results in production congestion and shortages.

Process flow related activities are incurred in moving products through the production process. Whenever products move to a new work center, activities to handle the material movement and to process the products are required. Long process flows require more activities associated with supervision. Process flow activities are related to process balancing activities. Usually the larger the area used for the production processes, the greater the demand for activities for balancing, communicating, and coordinating the production line.

Purchasing and materials control related activities concern activities incurred for the order, receipt, movement, and payment for materials. Examples include activities for supplier identification, certification and inspection of incoming units, handling and issuing materials into production. These activities require purchasing, receiving, stocking, and accounting personnel, as well as space for processing documents, inspection and storage

Quality related activities are incurred to insure that goods are produced to customer requirements and the standards of the manufacturer. These activities include preventive procedures like training, process documentation, and design for producibility. For instance, non-conforming items require activities for inspection, reworks, rejects, and scrap.

Change related activities are needed to accommodate alterations in product or process design due to customer, market, technology, or regulatory forces. Change related activities include changes in engineering design, bills of materials, material specifications and routings. These changes incur additional process balancing, process flow, purchasing, and materials control activities. This represents one example of interactions among various activities.

Since the data for the above activities are not measured in a desired fashion, this paper adopted the proxy measures with some modifications as in Banker and Potter (1994). We hypothesized that as work-in-process (WIP) increases, more process balancing activities are required to insure smooth production runs. More inventory requires more coordination of work orders, batches, and other resources. Just-In-Time (JIT), however, may reduce the need for those activities. Therefore a decline in WIP represents an improvement in inventory policies, which will imply a reduction in process-balancing activities. Although cost of WIP does not directly measure process balancing activities, it may capture the required level of process balancing activities.

Long and complex process flows may generate more handling and communicating activities. Banker and Potter (1994) used area per part (AREA), the total of production and warehouse/ storage area divided by number of different parts, to measure the amount of movement required in the plant. Larger area per part is assumed to require more flow related activities.

Purchasing and material control activities deal with purchasing, receiving, inspecting and storing materials. The number of purchase orders for direct materials and parts and the number of purchase requisitions from user departments (PURCH) represent purchasing activities. We therefore used the sum of the number of purchase orders and the sum of purchase requisitions as a measure of purchasing and materials control activities.

Data for quality-related activities are rarely kept in plants. Four different quality related activities such as preventive, appraisal, internal failure and external failure related activities are possible in plants. Because of limited data availability, however, we used the number of monthly reworks (REWORK) as a proxy for quality related activities.

Due to the changes of customer demands, market and technology, change related activities are required. These activities include changes in material specifications, engineering design, schedules, routings, and standards. These activities involve the work of manufacturing, industrial and quality engineers along with a portion of the effort expended in purchasing, materials control, and data entry. These change activities lead companies to incur additional overhead expense (Miller and Vollmann (1985)). In this paper, the number of monthly engineering change order (ECO) is used to measure change related activities.

The above activities summarize the support activities as shown in Table 1. These activities are hypothesized to influence overhead expense directly while they are driven by volume and structural complexity variables.

3.3. Measurement of Structural Complexity of Production

Structural complexity of production can be represented by several dimensions such as demand uncertainty, production scope and production scale, technology, work force policies, and product diversity (Banker and Potter (1994)). Breadth of product lines and/or lack of focus is one aspect of structural complexity in manufacturing. An increase in the number of product lines (NPRODLN) at a plant may lead to an expansion of demand for activities of materials handling, machine setups, supervision, scheduling, expediting and quality inspection. Plants with a narrow or focused product mix are more likely to have simpler operations and dedicate their resources such as equipment, support systems, and personnel to focused tasks.

When new products are introduced at a plant, workers will have difficulty adjusting to the production of new products. This will increase the product volatility. In contrast, if the firm has been producing the same products for a long time, the production process might have been already streamlined due to the learning curve effect. Therefore the uncertainty and complexity of production environment seem to vary with the portion of new products The portion of new products introduced

Table 1. Volume and Supporting Activity Variables & Measurements

Variables	Measurement
Direct labor	Direct labor costs (DLABOR)*
Process balancing	Work-In-Process (WIP)
Process flow	Area per part (AREA)
Purchasing & material control	Number of purchase orders and purchase requisitions (PURCH)
Quality	Number of reworks (REWORK)
Change	Engineering change orders (ECO)

* Words in parentheses are variable names used in estimation equation

within the last five years (NEW)[2] is used to capture the uncertainty and complexity of production environment

Production method influences the complexity of production process. Continuous production seems to have a stable production process with less complexity than the batch-type of production. If the percentage of batch production (BATCH) is high, then products are made in small batches, it is hard to dedicate resources to products and to enjoy economies of scale.

Congestion could increase production complexity. Especially when plants operate close to capacity, congestion may occur Congestion may make it more difficult to schedule, balance, and coordinate resources in a timely fashion. Especially, quality level will decrease when plants are congested and are not running smoothly (Roth and Albright (1994)). A degree of congestion (CONGESTION) is measured as the level of operation in excess of 85 of the capacity.

Banker and Potter (1994) identified age of plant (AGE) as an additional explanatory variable for production complexity. Older plants tend to add continuous but marginal improvements to existing technology resulting in less efficient and less flexible production processes than newer plants with a state-of-the-art technology. Therefore, older plants will have difficulty in producing and processing excellent quality products.

Production cycle time (CYCLETIME) may influence production complexity. The longer the production cycle time, the more complex the forecasting, scheduling, material handling, and other balancing activities are needed. JIT policies, TQM policies, and teamwork procedures could streamline the production processes that will reduce the production complexity.

Production scale is one example of structural complexity variables which may have an impact on supporting activities (Shank and Govindarajan (1992)) The net book value of plant and equipment (NETBV) is used as a measure of production capacity. Operationalization of structural complexity variables are summarized in Table 2.

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2) Five-year period is assumed to be long enough for learning effect s to be materialized

Table 2. Structural Complexity Variables & Measurements

Variables	Measurements
Production Scope	Number of production lines (NPRODLN)
Market Change	Percentage of new products introduced within the last 5 years (NEW)
Production Method	Percentage of batch production (BATCH)
Congestion	Operation in excess of 85% of capacity (CONGESTION)
Age	Plant's age (AGE)
Length of production process	Cycle time (CYCLETIME)
Production scale	Net book value of equipment (NETBV)

3.4. Measurement of Volume

Production volume or other volume-related variables have been considered major variables influencing manufacturing overhead. Previous cost driver studies provided evidence on the significant impact of volume-based drivers on overhead (Foster and Gupta (1990), Banker, Potter and Schroeder, (1993), Banker and Johnston (1993)). Volume-related drivers might have a direct effect on overhead by increasing indirect material and indirect labor costs. Moreover volume-related variables may change the level of support activities and hence the level of overhead. For example, expansion of volume will require more balancing activities. We might call this an indirect effect of volume-related drivers on overhead We used direct labor cost as a surrogate of volume-related activities (DLABOR).

3.5. Measurement of Overhead

A dependent variable used in this type of analysis is plant overhead as measured by dollar terms or by physical units. Most studies used total overhead (Banker et al. (1993)) while some studies used individual overhead items or physical measure of overhead such as indirect labor hours (Banker and Johnston (1993)) This study used both total manufacturing overhead (OVHD) and the number of indirect manufacturing personnel (INDPER) as dependent variables Note that the number of indirect manufacturing personnel (INDPER) is used as a surrogate for indirect labor hours

3.6. Cost Behavior Estimation Models

To estimate the effect of supporting activity variables and direct labor activity on overhead, the following equations are used.

$$OVHD = \alpha_0 + \alpha_1 DLABOR \qquad (A1)$$
$$OVHD = \beta_0 + \beta_1 WIP + \beta_2 AREA + \beta_3 PURCH + \beta_4 REWORK + \beta_5 ECO \qquad (A2)$$
$$OVHD = \gamma_0 + \gamma_1 DLABOR + \gamma_2 WIP + \gamma_3 AREA + \gamma_4 PURCH + \gamma_5 REWORK + \gamma_6 ECO \qquad (A3)$$

$$INDPER = \alpha_0 + \alpha_1 DLABOR \qquad (B1)$$
$$INDPER = \beta_0 + \beta_1 WIP + \beta_2 AREA + \beta_3 PURCH + \beta_4 REWORK + \beta_5 ECO \qquad (B2)$$
$$INDPER = \gamma_0 + \gamma_1 DLABOR + \gamma_2 WIP + \gamma_3 AREA + \gamma_4 PURCH + \gamma_5 REWORK + \gamma_6 ECO \qquad (B3)$$

Equations (A1) and (B1) estimate the explanatory power of volume-related variable only while equations (A2) and (B2) estimate the explanatory power of supporting activity variables. Only volume-related variables and supporting activity variables are combined together to estimate the overhead variation in equations (A3) and (B3). By comparing R^2's of (A1) and (A3) we can test the marginal improvement in explanatory power of supporting activity variables over the direct labor variable. Similarly comparison of R^2s of 1-2 and 1-3 will show the statistical significance of volume-related variables in explaining the variation of overhead

4. Description of Variables

The tables 3 to 5 describe the summary statistics of the variables used in this study. Average of total manufacturing costs is around 24.3 billion won with a median of 15.1 billion won. A standard deviation is about 24.8 billion won which is greater than the average. Cost structure is a major concern for

Table 3. Descriptive Statistics of Cost Related Data (unit: million won)

	Mean	Std Dev	Skewness	1st decile	Median	9th decile
Manufacturing Costs (Won)	24,275	24,838	1 70	3,949	15,134	59,004
Direct Labor (%)	14 56	10 96	3 52	7 1	12	22
Direct Material (%)	57 73	19 99	-1 07	30 0	64 4	77 8
Overhead (%)	27 95	14 47	1.19	9	23 75	49 3
OVHD (Won)	6,598	8,775	3 31	603	3,843	12,616
DLABOR (Won)	3,576	4,867	2 61	385	1,391	10,577
INDPER (Won)	91	80	1 67	22	68	209
Number of Employees	242	228	2 01	50	167	580

managers. Direct materials cost is the largest manufacturing cost element, 58% of the total manufacturing cost. Manufacturing overhead is around 28% of the manufacturing cost, whereas direct labor cost is about 15% of overhead. These data exhibit the importance of overhead cost management compared to that of direct labor cost management. There is a wide range of values for overhead percentage with the 1st decile at 9% and the last decile at 50%. This wide variation may be due to the differences of production methods among the sample plants.

Manufacturing overhead (OVHD) is calculated by multiplying total manufacturing expense by the overhead percentage. OVHD has a mean of 6.6 billion won and a median of 3.8 billion won. To be noted is that most of the variables in Table 3 including OVHD are skewed to the left. Skewness in OVHD is also found in Foster and Gupta (1990) and Banker et al. (1993). While the total number of employees has an average of 242, number of indirect manufacturing personnel (INDPER) has a mean of 91 representing 38% of the total number of employees.

Table 4 summarizes the descriptive statistics of activity related and other relevant variables. Work in process inventory (WIP) shows the smallest mean of 537 million won among inventory items and a median of 213 million won. Material inventory has a mean of 791 million won and a median of 419 million. Finished goods inventory has the largest mean of 1,029 million won and a median of 366 million won. All of these inventory-related figures show a left-ward skewness.

The average area per part (AREA) is 37 m^2 with a huge

Table 4. Descriptive Statistics of Support Activity and Related Variables

	Mean	Std Dev	Skewness	1st decile	Median	9th decile
WIP	536 85	821 05	2 71	0	212 5	1320
MATERIAL	790 53	1141 73	3 01	95	419	1572
FG	1,028 84	1559 93	3 19	96	366	2781
AREA	36 86	136 68	6 52	0 875	5 65	38 91
MSPACE	2,331 29	3923 26	3 28	268	1300	5341
SSPACE	538.36	615.15	1 95	61	300	1471
PURCH	183 32	270 51	3 33	20	90	500
NSUPPLY	50 39	42 57	1 78	9	40	120
PURORDER	152 01	252 44	3 77	5	67 5	360
PURCLAIM	206	327 55	2 95	18	80	525
REWORK	6.55	9 88	2 46	0	3	20
ECO	6 55	11 98	3 97	1	2	20

Note. WIP, MATERIAL and FG in million won, AREA, MSPACE and SSPACE in m^2

standard deviation of 137 m^2 This variable shows an extreme variation. Average space used for manufacturing (MSPACE) is 2,331 m^2 and the median is 1,300 m^2 Storage and warehouse space (SSPACE) is about one fourth of manufacturing space.

Plants have about 50 suppliers (NSUPPLY) with the 1st decile at 9 suppliers and the last decile at 120 suppliers. Purchasing activities are represented by the numbers of purchase orders (PURORDER) and purchase requisitions (PURCLAIM). The number of monthly purchasing order shows an average of 152 times with the median of 68 times while PURCLAIM has a higher mean of 206 and a median of 80.

Monthly average of reworks (REWORK) is about 7 times with a median of three times. It shows a very high standard deviation of 25 times and a very large positive value of skewness The average number of engineering change order (ECO) is around 7. These figures show an extremely high skewness. Most firms have few reworks and ECO. This may be due to the fact that a large portion of the sample firms supply most of their products to one major auto assembler.

In addition to the activity and volume measures, the descriptive statistics for the structural production complexity

Table 5. Descriptive Statistics of Structural Complexity Variables

	Mean	Std. Dev	Skewness	1st decile	Median	9th decile
NPRODLN	12.62	13.54	3.17	3	8	30
BATCH	34.82	33.90	0.75	0	23.5	100
NEW	68.89	28.68	-0.78	23	79.5	100
CYCLETIME	1.79	2.05	4.15	0.3	1	3
CONGESTION	1.94	2.30	2.70	0	0	7
AGE	15.46	8.56	0.63	4	15	24
NETBV	10,796.24	10,281.26	1.91	1,772	7,699	22,772

variables are presented in Table 5. Average number of product line (NPRODLN) shows a great variation with a mean of 12.6. Half of the plants have more than 8 product lines. The median for batch production (BATCH) suggests that about half of the sample plants produce 23% of their auto components in small batches. The first and the last decile are 0% and 100% respectively, showing that some firms have continuous flow production and others produce all of their products in small batches

On average about 69% of their products are introduced within the last 5 years. A large percentage of newly introduced products (NEW) indicate that plants must rearrange their production processes quite frequently. Cycle time (CYCLETIME) shows an average of 1.8 days and a standard deviation of 2 days The first and the last decile are 0.3 days and 3 days respectively.

The average of capacity utilization (CAPACITY) is about 86.9% while the median is less than 85% Capacity utilization variable is measured following Banker and Potter (1994) where 85% capacity utilization is used as a threshold Specifically a zero value is assigned if a plant is operating below 85% capacity and positive values are assigned if capacity utilization is in excess of 85%.

The median age (AGE) of the sample plants is about 15 years. The first and the last decile are 4 and 24 years respectively. The mean book value for property, plant, and equipment invested in the plant (NETBV) is 10,796 million won while the median value is 7,699 million won.

The descriptive statistics of the variables demonstrate that there exists a huge variation in activity and complexity variables in our sample plants. Since this is a cross-sectional study, this variation among the sample plants will help investigate the impact of support activity and structural production complexity variables on overhead

Table 6 summarizes the results of simple Pearson correlation both among supporting activity variables and among direct labor and complexity variables. Panel A shows that WIP variable is positively correlated with PURCH variable and REWORK variable is correlated with PURCH variable. Panel B shows a very high correlation between DLABOR and NETBV variables. Some may argue that two variables are alternative measures for the same variable, production scale. NETBV, however, represents production capacity while DLABOR variable represents actual production activity. Therefore it is not surprising to observe a

Table 6. Panel A: Simple Pearson Correlation Among Activity Variables

	WIP	AREA	PURCH	REWORK
WIP				
AREA	0 153			
PURCH	0 264**	-0 067		
REWORK	0 034	-0 005	0 255**	
NECO	0 184	-0.034	-0 024	0.051

Note * $p < 0\ 10$, ** · $p < 0\ 05$; *** · $p < 0\ 01$

Table 6. Panel B: Simple Pearson Correlation Among Direct Labor and Production Complexity Variables

	NPRODLN	BATCH	CHANGE	CYCLE	CAPACITY	AGE	NETBV
NPRODLN							
BATCH	-0 074						
CHANGE	0.039	-0.094					
CYCLE	-0 163	0 176	-0 268**				
CAPACITY	0.352***	-0 116	-0 094	-0 083			
AGE	-0 003	-0 004	-0 199*	0 205*	-0 089		
NETBV	0.151	0.163	-0.218*	0.043	0.156	0.281*	
DLABOR	0 217*	0.188	-0.177	0.000	0 175	0.254**	0.753***

Note· * · $p < 0\ 10$, ** : $p < 0\ 05$; *** $p < 0\ 01$

high correlation. We need caution in interpreting these two variables. A significant positive correlation at $p<0.05$ level is also observed between CAPACITY and NPRODLN and a negative correlation between CHANGE and CYCLE.

5. Regression Results

Support activity variables used in this study are work-in-process (WIP), area per part (AREA), number of purchase orders and purchase requisitions (PURCH), number of reworks (REWORK), number of engineering change order (ECO), and direct labor costs (DLABOR). To isolate the effect of each activity variable on overhead, we need to control for the effect of other activity variables. Multivariate regression analysis is recommended as one of the most appropriate methods (Banker, Potter and Schroeder (1993)).

The regression results examining the link between manufacturing overhead and production activities are presented in Table 7. R^2 values and F values show that these equations are significant. This implies that direct labor variable and the set of supporting activity variables are important cost drivers of manufacturing overhead. Equations (A1) & (A3) show that direct labor activity variable (DLABOR) is still an important cost driver of manufacturing overhead. This result is consistent with the traditional argument that volume-based driver is an appropriate basis for allocating overhead. Among the set of supporting activities, WIP and PURCH are shown to have a significant positive impact on overhead as shown in equation (A2) and (A3). Although not significant, other activity variables show a positive coefficient as expected. The third regression used both volume and supporting activity variables as independent variables while the first and the second regression equation used only volume variables and supporting activity variables respectively. The first equation using only direct labor cost variables explains about 39% of the overhead variation The second equation with supporting activity variables as independent variables explains about 55% of the overhead variation. To note is that condition number test (Green (1997)) did not show multi-collinearity problem.

Table 7. Effects of Supporting Activity & Direct Labor Activity Variables on Manufacturing Overhead

Variable	Equation (A1)	(A2)	(A3)
Intercept	2,567**	694	-16 59
WIP		6 5***	4 65***
AREA		1 01	2 71
PURCH		7 49**	6.86***
REWORK		85 13	78 40
ECO		68 09	58 21
DLABOR	1 13***		0 53***
F Value	46 190 ($p < 0$ 0001)	16 886 ($p < 0.0001$)	17 252 ($p < 0$ 0001)
R^2 (Adj R^2)	0 391 (0 382)	0 554 (0 521)	0.607 (0 572)

Note: * $p < 0.10$, ** . $p < 0$ 05, *** $p < 0.01$

By comparing the explanatory powers of three different models, I tested the incremental contribution of volume variable and supporting activity variable set respectively in explaining overhead variation. To assess the incremental contribution of volume variable and the set of supporting activity variables respectively, F statistic is calculated using the following equation.

$$F = \frac{(R^2_{new} - R^2_{old}) / df_1}{(1 - R^2_{new}) / df_2}$$

R^2_{new}. R^2 after adding the new regressor(s)
R^2_{old}: R^2 under the old model
df_1: number of new regressor(s)
df_2: number of parameters in the new model

F statistics for the volume variable and the set of supporting activities are 9.036 and 7.36 respectively both with $p < 0.01$. F-test result demonstrates that the direct labor cost variable and the supporting variable set provide significant improvement in the explanatory power of the equation (A1) and equation (A2) respectively. These results are consistent with those of Banker, Potter, and Schroeder (1993) which showed that both volume and supporting activity variables are significant in explaining variation of overhead.

Table 8. Effects of Supporting Activity and Direct Labor Activity Variable on Indirect Manufacturing Personnel

VARIABLE	EQUATION (B1)	(B2)	(B3)
INTERCEPT	46 79***	36 76***	24 67***
WIP		0 05***	0 02**
AREA		-0 05	-0.02
PURCH		0.08***	0 08***
REWORK		0 18	0 07
ECO		2 16***	1 90***
DLABOR	0 01***		0 01***
F Value	98 051 (p<0 0001)	17 118 (p<0 0001)	32 428 (p<0.0001)
R^2 (Adj R^2)	0 577 (0 571)	0 557 (0 525)	0 744 (0.721)

Note * $p < 0\ 10$, ** $p < 0\ 05$, *** . $p < 0.01$

The second set of regression equations estimates the effect of volume and support activity variables on the number of indirect personnel as shown in Table 8 Direct labor cost variable explains about 58% of the overhead variation as in regression equation (B1) and the set of supporting activity variables explains about 56% of the overhead variation Volume and supporting activity variables altogether explain about 74% of the variation in the number of indirect personnel.

As with the case of Table 7, direct labor variable (DLABOR) is found to be a significant explanatory variable of indirect manufacturing personnel (INDPER). In addition to WIP and PURCH, engineering change order activity (ECO) variable has a significant positive coefficient As with the first set of regression equation, I investigated the incremental contribution of the direct labor cost variable and the set of supporting activity variables. *F*-statistics for volume and supporting activities are 43.7 and 9.78 respectively with $p < 0.01$. The *F*-test result shows that the set of supporting activity variables provides significant improvement in explaining the variation of indirect manufacturing personnel in addition to the volume variable. These results strongly demonstrate the usefulness of structural production complexity variables in explaining overhead. Condition number test (Green (1997)) did not show multicollinearity problem

The *p*-values of less than 0.0001 indicate that the regression equations are highly significant. We can conclude that variation in manufacturing overhead and the number of indirect manufacturing personnel is explained by the volume and production complexity variable. This result is true in both cases of dependent variables. R^2 value for the equation (B3) is 0.74, which is higher than R^2 of 0.60 for the equation (A3). This indicates that these activity variables are related more with the number of indirect personnel than the overhead costs.

Volume is measured by direct labor costs (DLABOR). Direct labor cost has a coefficient of 0.53 with a significance of 0.0037. This demonstrates the significance of volume effects after controlling for the effect of activity variables. Volume variable is a major determinant of manufacturing overhead and the number of indirect manufacturing personnel. This result is consistent with previous studies (Foster and Gupta (1993), Banker et al. (1993)).

Supporting activity variables seem to be significantly related with overhead. WIP (work-in-process) variable representing process balancing activities has a coefficient of 4.65 at a significance level of 0.0001. Manufacturing overhead costs seem to increase with the level of work-in-process inventory. This is consistent with the Just-In-Time philosophy. We may conclude that the lower the WIP inventory level, the lower the overhead resource consumption.

PURCH is a measure of purchasing and material handling related activity. This variable has a coefficient of 6.86 and a significance level of 0.013. A positive coefficient indicates that overhead increase with the number of purchasing and materials handling activity. Although other activity variables such as AREA, REWORK, and ECO are not statistically significant, they have positive values. This indicates that these activities tend to lead to higher overhead costs. The relationship of these variables with overhead, however, is not as strong as that of WIP, PURCH, and DLABOR.

The regression result implies that the five activities of process balancing, process flow, purchasing and material handling, quality inspection and change combined with direct labor cost can explain about 61% of the variation in overhead. All of five variables have positive coefficients as expected with two variables having a statistical significance From a cost management perspective, we can argue that the efficient control of these five activities will reduce manufacturing overhead.

Similar to the case of the first set of regression equations, WIP has a positive coefficient of 0.015 with a statistical significance of 0.05. The level of WIP seems to increase the number of indirect manufacturing personnel. PURCH variable also has a positive coefficient with a high statistical significance. This again implies that purchase and materials handling activity will lead to an increase in the number of indirect personnel. In addition to WIP and PURCH, number of engineering change order (ECO) variable has a statistically significant positive coefficient. ECO variable is included as an additional explanatory variable.

Direct labor cost (DLABOR), a volume measure, is again considered important in this model after controlling for the effect of activity variables. It has a positive coefficient with the statistical significance of 0.0001. We may conclude that the volume variable has a positive effect on manufacturing overhead and number of indirect personnel. Again this is consistent with the previous results of the cost driver studies.

6. Results Relating Production Complexity to Activities

Previous cost driver studies (Banker et al. (1995), Foster and Gupta (1990), Banker and Johnston (1993)) focused on the direct effect of various cost drivers on manufacturing overhead. This study, however, hypothesized a hierarchy of cost drivers and attempted to analyze the effect of structural production complexity drivers on supporting activity drivers which will in turn have a direct impact on manufacturing overhead. Here, we hypothesized that structural production complexity drivers will have an indirect effect on manufacturing overhead through supporting activity variables mentioned above.

Table 9 summarizes the effects of structural production complexity variables on supporting activity variables. Only two regression equations with dependent variables of WIP and PURCH show statistical significance As shown earlier these two variables were found to be significant in explaining the variation of overhead. Since these two variables are major determinants of overhead, we may then conclude that structural complexity

Table 9. Effects of Structural Production Complexity Variables on Direct Labor and Supporting Activity Variables

VARIABLE	WIP	AREA	PURCH	REWORK	ECO
INTERCEPT	688 55**	43.64	-35 44	8 96*	3 83
NPRODLN	-5.46	0.22	2 71	0 01	0 03
BATCH	-3.23	-0 34	0 34	-0 03	0 01
NEW	-6 15**	0 09	-0 07	-0 04	-0.07
CYCLETIME	13.52	5.95	-3.62	-0 05	-0 25
CONGESTION	34 41	-6 47	24 33*	1 28**	-0 34
AGE	-10.39	-1 43	6.31*	0 01	0 37**
NETBV	0 05***	0.001	0 006*	0 00001	0 0002
DLABOR	0.055**	-0.002	-0.008	-3 61E(-5)	-1 31E(-4)
F Value	9.368 (p<0 0001)	0 241 (p<0 9372)	2 591 (p<0 0201)	1.427 (p<0 2095)	1 829 (p<0.0962)
R^2 (Adj. R^2)	0 498 (0 445)	0 025 (-0 078)	0 216 (0 132)	0.135 (0 039)	0 163 (0.074)

Note· * · p < 0 10, ** . p < 0.05; *** · p < 0 01

variables are effective in explaining the variation of supporting activities. Cost management should be considered from a strategic viewpoint as well as from an operation management viewpoint. Accountants should look for cost management solutions from a long-term strategic planning as well as from daily operations

NETBV variable has significant positive coefficients in explaining process balancing activity (WIP) and purchase control activity (PURCH). These results imply that larger production scale increases process balancing activity and similarly purchasing control activity. CONGESTION variable also has significant positive coefficients in explaining variation of purchase control activity (PURCH) and rework activity (REWORK). This indicates that congestion increases the complexity of production process and hence purchase-control activity and rework activity. AGE variable is found to have a significant positive impact on purchasing (PURCH) and engineering change activities (ECO). It will be hard for old plants to handle flexible manufacturing requirements of frequent engineering changes Aged plants tend to have a relatively fixed production setting which demands more material control activity than a flexible production process when product mix becomes diverse.

7. Conclusion

Traditional costing assumes that only volume is a significant driver of overhead. ABC supporters, however, assert that complexity variables are significant drivers of overhead. This paper tested whether volume and complexity-related drivers are significant in explaining variation of overhead.

This paper classified cost drivers into two different levels. The first level drivers are classified into volume-related and support activity drivers; the latter of which are derived from an operations management viewpoint. The higher level cost drivers are structural drivers that are assumed to influence volume-related and support activities.

Cost structure analysis shows that manufacturing overhead percentage is twice as big as direct labor cost percentage, which implies the importance of overhead cost management. Empirical results show that both volume and support activities are positively associated with overhead. Each of volume and support activity variables showed significant marginal contribution to the explanation of overhead variation. This result supports assumptions of both traditional and ABC systems suggesting that both volume and complexity-related support activity drivers are useful for cost allocation and cost management purposes. Among the support activities, especially process balancing activities, purchasing control activities, and change activities showed significant positive effects on manufacturing overhead.

The higher level of tests showed that selected structural complexity variables explain the variation of support activity drivers, especially process balancing, purchasing control and change activities. This result partly supports the notion that structural production complexity drivers have significant influence on the level of support activities. We may conclude that cost management should be considered from a strategic viewpoint as well as from an operation management viewpoint. Accountants should look for cost management solutions from a long-term strategic planning as well as from daily operations.

Note that the above support activities are selected as the significant variables affecting manufacturing overhead resources. We could then infer that structural production complexity variables changes overhead resource consumption indirectly through the above support activities. We could not find, however, any meaningful relationship between structural production complexity, and process flow activities and quality related activities.

This study has several limitations. Possible variation in overhead measurements among 74 plants might have caused some noise in coefficient estimation. By limiting the samples to a single industry, we were able to control industry effects. Single industry results, however, may not be generalizable to all industries. Variable measurements for the supporting activity variables are subject to criticism especially when data are collected directly from respondents. Moreover some portions of the manufacturing overhead are facility-sustaining expenses whose cost drivers may not be well identified.

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