Adoption and implementation of group technology classification and coding systems: insights from seven case studies

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Results are reported from an empirical study of classification and coding (CC) system usage among manufacturers. The investigation, selection, justification, implementation and operation of CC systems by six user firms are presented in case study form. A case history of a former CC system user is also presented. User characteristics and experiences are compared and analysed across the seven cases. The paper concludes with managerial and research implications regarding CC system selection, justification, implementation and usage.

1. Introduction

Group technology (GT) is a manufacturing philosophy which advocates simplification and standardization of similar entities (parts, assemblies, process plans, tools, instructions, etc.) in order to reduce complexity and achieve economies of scale effects in batch manufacturing. One vehicle for implementing GT is classification and coding (CC), a methodology which organizes similar entities into groups (classification) and then assigns a symbolic code to these entities (coding) in order to facilitate information retrieval.

CC is typically viewed as a computer-based technology. The adoption and implementation of computer-based manufacturing technologies have been discussed by Meredith (1981), Rosenthal (1984), Ettlie (1988), and others. A limited subset of the literature focuses on the selection, implementation and usage of GT codes. Hyer and Wemmerlöv (1985), in a non-empirical paper, discuss GT code structures, uses, and prescriptive guidelines for implementation. Hyer and Wemmerlöv (1989) present results from a broad-based survey of 53 GT users, 33 of whom used CC. Wemmerlöv (1990) documents and analyses recommended and actual selection and justification procedures for GT software, using information from software vendors, interviews with manufacturers, and published sources. Practitioner articles present individual case studies of CC implementation and usage (Desai 1981). In this paper, we strike a balance between an in-depth single facility study and a more broad-based multi-facility survey by studying a small number of cases on a focused aspect of GT.

The paper describes an empirical study of classification and coding system usage among seven US manufacturers located in the Midwest. The search, selection, justification, implementation and operation of the CC systems are presented in case study form. User characteristics and managerial issues are then compared and analysed across these cases. The paper proceeds as follows: section 2 provides an overview of GT.
2. Group technology and classification systems

Group technology principles may be applied to any conceivable entity ranging from manufactured parts and capital equipment to decision processes and human characteristics (Wemmerlöv and Hyer 1992, Gallagher and Knight 1986). GT aims to take advantage of similarities that exist among items, and to increase effectiveness by:

1. allowing similar, recurring activities to be conducted together (e.g. part family scheduling);
2. standardizing similar activities to control activity proliferation and better utilize resources (e.g. control over new designs);
3. supporting convenient information retrieval so that historical information is accessible and usable (e.g. retrieval and modification of an old process plan to suit a newly designed part released to manufacturing).

A part family is a collection of similar parts that share specific design and/or manufacturing characteristics, identified for a well-defined purpose. All parts in a family may require similar treatment and handling methods, and efficiencies are achieved by processing the parts together. Manufacturing efficiencies are gained from reduced set-up times, part family scheduling, improved process control, standardized process plans, standardized instructions, group layouts, higher quality, and in general, increased learning. Product design advantages are gained when design engineers retrieve existing drawings to support new products and when features are standardized to prevent part proliferation.

Three types of activities are necessary in applying group technology:

1. determination of critical part attributes that represent the criteria for part family membership;
2. allocation of parts to established families; and
3. retrieval of part family members and related information.

Classification and coding systems can assist in these tasks by providing a structure for the classification of parts into groups based on selected part attributes, and by assigning a code to each part (Hyer and Wemmerlöv 1984, 1985, Groover and Zimmers 1984). This code aids information retrieval for that part.

A code is a string of alphanumeric characters which, when interpreted, provides information about that part. This is in contrast to a part number, whose purpose is item identification, not description (Mather 1982). Although so called 'significant part numbers' contain some meaningful information about parts, these are not considered 'codes' for the purpose of this study (Elliot 1985).

The process of coding a part is preceded by the classification of the part, that is the determination, for each critical attribute, of the class to which the part belongs. Each such class is represented by a code identifier. For example, design attributes for a
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wooden bookshelf might be the number of shelves, shelf width and depth, and colour of
the stain. On the other hand, manufacturing attributes might be how the wood is cut,
how the shelf is assembled, and the methods for actually staining the shelf. The process
of coding and classification may be completely manual or computer-assisted with
interactive expert-system like queries from the computer (Hyer and Wemmerlöv 1989).

Part families can be determined by using codes. First, the part family application
objectives must be determined. Part families for design applications often rely on quite
different part attributes than those for manufacturing applications; hence, the reasons
for generating part families must be made clear. Once the objectives are determined,
relevant part family attributes are identified, and codes that correspond to these
attributes are specified. The data base of coded parts is then used to retrieve part family

2.1. Existing GT classification and coding systems

Many commercial and non-proprietary coding systems are in existence (Hyer and
Opitz system, developed in the 1960s in West Germany, is perhaps the best known. It is
applicable to both machined and non-machined parts, and has been widely used in
Europe (Opitz 1970, Opitz and Wiendahl 1971). The Brisch Birn system was developed
in the UK over 40 years ago. This 'system' is actually a coding shell customized to a

More recent commercial coding systems take advantage of the databases which are
made possible by today’s advanced computing technology. Rather than storing strings
of symbols that represent classes into which an item falls, these databases capture the
exact dimensions or attributes of a particular item. Often, this information is structured
as a relational data base which may be accessed using a 'natural language' interface
(despite the fact that these modern systems do not always use coded data, we will use the
term CC systems throughout this paper to cover both older and newer systems). Three
vendor systems are briefly discussed here.

John Deere has been using and developing GT systems since 1976. Recently, Deere
Tech Services was created to sell GT systems and consulting services. The Deere Tech
system employs a 35-digit code, not shown to the user, while communicating to the user
via natural language style computer queries. The Organization for Industrial Research
(OIR) sells GT systems with code and analysis programs. A recent survey of 33 CC
users found that 17 used OIR systems (Hyer and Wemmerlöv 1989). OIR's system
captures exact item data and generates a code which summarizes the information. The
CimTelligence system uses a natural language interface that understands the meaning
and context of words and sentences. The OIR and CimTelligence systems both use
relational databases. All three vendor systems include, besides a GT database, various
program modules that assist in specific activities such as cost estimation, product
design, tooling control, part family formation, production cell configuration, and
process planning.

Rather than employing a commercial system, firms may choose to combine a
(perhaps existing) company database with a database organization and extraction tool
to achieve GT intents. One such generic tool is a general purpose information tree
processor called the decision and classification information system (DCLASS). In
addition to providing a mechanism for classifying and organizing data, DCLASS
allows a company to capture expert logic, e.g. for computer-aided process planning
In addition, a firm may choose to develop its own engineering database and CC system for any number of reasons, including lower cost or particular software system integration needs.

3. Sample firm selection

The seven firms described in this paper were culled from a larger population of Wisconsin firms involved in a mail survey study. The survey goals were to determine whether the respondent was a CC user or not, how much experience with or awareness of CC the firm had, the technological progress of the company, and the economic justification approach used for CC systems.

The six-page questionnaire was distributed to plant and manufacturing managers in 94 Wisconsin manufacturing firms with over 500 employees thought to be likely users of CC (e.g., machine tool manufacturers were included while chemicals processors were not). These firms belonged to the two-digit standard industrial classification (SIC) code categories of 25 and 34-39, covering furniture and fixtures, fabricated metal products, all types of machinery, transportation equipment, engineering and medical instruments and miscellaneous other manufacturing. Further, the minimum employee base of 500 was imposed based on the assumption that only larger companies would have the resources to seriously consider and implement classification and coding. The firms were selected from a trade association database containing entirely firm-reported information.

A 48% survey response rate was achieved, representing 45 usable surveys. Analysis of the responses, coupled with telephone interviews, led to the determination that CC use was either non-existent (60% of the respondents), highly localized in the firm (27%), or large-scale (13%). We define a large-scale user as one whose CC system has some significant penetration in that codes are used by several departments, for several part types, and/or are capable of providing information of particular detail. Such systems are computer-based, may have been acquired with some strategic use in mind and have several functional area users. In short, large-scale CC systems tend to have some pervasiveness in the company.

Six of the respondent firms were currently using, and one firm had recently discarded, large-scale CC systems. Additional in-depth telephone interviews, coupled with some on-site interviews, observations and document review, were conducted for these seven firms.

4. Case studies of six large-scale coding system users

4.1. Company A

Company profile. Company A is a producer of engineered-to-order paper machines, some of which produce paper in 30-ft widths at a rate of 1 mile per min. These one-of-a-kind systems contain up to 7 million parts, many of which are specific to a single custom-made machine.

Selection/justification. Part proliferation is a major problem for Company A. Not only does each machine generate thousands of unique parts, but once created, these drawings must remain on file for an indefinite amount of time should a customer wish a replacement part. Recognizing that such complex products require sophisticated engineering and production controls, Company A commenced localized use of a modified Brisch Birn type part code in the late 1950s. Consideration of full-blown CC
usage started in 1967 when they expanded the Brisch Birn type coding system. This CC system development was justified economically using a traditional approach with an internal rate of return criterion. Justification data were gleaned from vendors, trade journals and seminars.

**Implementation experience.** By 1973, the company developed (with consultant support) an in-house modified Brisch Birn style CC system to eventually accommodate all types of manufactured and purchased parts. Raw materials and hardware items were easily coded, but machined and fabricated parts were not due to their extreme variety and complexity. For example, 3 years were spent structuring a classification scheme for parts belonging to a section of one particular product, leading to 137 different classifications. In time, a 31-digit polycode (Wemmerlöv and Hyer 1985) above the basic code was proposed. Although this code represented 31 sets of variables, it was still inadequate for support of computer-aided process planning and would generate only rough part families.

Since the system’s inception in the late 1950s, all purchased piece-parts, raw materials and hardware have been routinely added to the database. The system is used ‘100’s of times a day’, primarily by purchasing, costing, estimating, design engineering and manufacturing engineering personnel. Purchasing and costing department activities are, in particular, dependent on the system, explaining the disciplined system maintenance. Specific current applications include design information retrieval, part variety reduction, and product cost estimation. Company A relies on the engineers’ experience, rather than the CC system, in devising part families for cellular manufacturing. Major system benefits have changed over time. Fifteen years ago the primary benefits were seen to accrue from improved raw material utilization while major current benefits arise from part standardization, reduced pattern and casting costs, and improved machine tool utilization. Speedy part retrieval is still considered a major benefit.

Company A conducted a thorough system review in 1984 and in 1988 considered briefly, but rejected, CC system expansion. Pressure to expand the system came from diverse company functions. In particular, the manager of subcontracting saw use in vendor communication and pricing. However, millions of dollars would have been required for the data capture of all manufactured parts. Projected benefits were expected to exceed costs ten years after system expansion, but it was thought that few benefits would be gained during the first years of database preparation. This high cost of data capture and lack of immediate tangible payback led to further postponement of manufacturing parts coding. Some in the company felt the firm should have started fully coding manufactured items in 1973 itself and believe that each year manufactured parts remain uncoded a comprehensive CC system benefit realization is postponed.

Company A is satisfied with the in-house development decision. However, it suggests that coding is easier to apply to standardized products, where parts are not overly complex and are used across many products in the product line, than to customized products like printing presses. The firm, therefore, advises other companies considering a CC acquisition to analyse the variety of their parts. If parts are relatively standardized, Company A recommends the purchase of an existing CC system, especially one suited for those specific materials or parts. However, if great part variety exists, in-house development with consultant support is recommended. Also, staff with intimate product knowledge must be involved in the classification and coding development process.
4.2. Company B

Company profile. Company B's CC system has been in operation over ten years but is currently being reassessed. This maker of farm tractors has the first computer-based installation of a Brisch Birn Associates CC system (Company A's system, while Birsch Birn style, was developed in-house without Brisch Birn support).

Selection/justification. The original code system has undergone many modifications since its first implementation. The project was approved via a traditional formal economic justification with payback criterion using quantitative data gathered from the vendor, trade journals, and user companies. Brisch Birn provided some of the contacts to other companies. Original system objectives were to assist in design retrieval and part standardization. However, part family scheduling and graphical cost analysis abilities have also been employed.

Implementation experience. After conducting a sampling study to determine CC's potential usefulness, full system implementation began in December 1977, and was completed in August 1978. One-hundred and fifty thousand parts were coded (based on their shape) and entered into the database during these 10 months. This included all raw materials, purchased parts, machined/fabricated parts, sub-assemblies and end-items. The primary CC system user group has been, and continues to be, design engineering. Manufacturing engineering does not use CC for GT applications such as determination of part families for cellular manufacturing, and any CC system usage for other manufacturing purposes is infrequent.

In 1984, Company B merged with a competitor firm. Since then, efforts have been made to accommodate both companies' part numbering systems. At this point, integration is not complete, but their computer systems allow cross-referencing of parts (Hyer and Wemmerlöv 1989, discuss that locating designs in one plant for use in another was a tremendous advantage to one multiplant company). While Company B believes acquisition of the CC system was 'a very wise choice', post-merger company divisions have taken varied attitudes toward the system. Each division has a different rate of data maintenance, i.e. some divisions do not keep the CC system up to date by entering new parts. Now less than 50% of new parts are coded company-wide. However, the original Company B division continues to code 100% of new parts.

Management support for GT and CC was high at first, as was general project enthusiasm. With time however, this enthusiasm has diminished and the CC system suffered as general staffing and support resources fell due to budget pressures resulting from the merger. At this time Company B is investigating the system usage by monitoring the applications and the type of users. The firm is considering moving to a selective coding of parts in the future so that only parts with a higher chance of subsequent information retrieval are coded.

Company B stresses that an ideal CC system must respond with retrieval information quickly, must be easy to use, and should be used by many functional areas (none of which occur now). They also feel that CC is not worth the high cost if it is only used to identify part families for cellular manufacturing, and state that other inexpensive and relatively effective methods exist for this purpose (visual inspection, production flow analysis). The low usefulness of the company's own system for the purpose of cellular manufacturing design seems to be reflected by the fact that production cells are created without relying on the CC system. This points to the very different (typically functional area-dependent) needs that a CC system must meet.
Further, CC system usage is complicated, both for coding and information retrieval. A complex part can take two hours to code and the coding process is entirely manual. If artificial intelligence-type interfaces were available, as one user at Company B suggested, coding could be computer-assisted. Ideally, a CAD interface would code directly from CAD graphical attribute files.

4.3. Company C

Company profile. This farm and lawn equipment plant keeps track of 60,000 active part numbers.

Selection/justification. A comprehensive CC system was installed in 1984 and implemented under the direction of a group technology co-ordinator. The vendor was another company division that sells manufacturing software and consulting services (Deere Tech Services). A traditional economic justification approach was taken, with an internal rate of return of 831% and a less than 1-year projected payback. The intangible benefits of having a common engineering database accessible by all engineers and the ability to contain part proliferation were included in the acquisition considerations. All system justification and implementation information was received from the vendor who also provided help with coding and system analysis training.

Implementation experience. The CC system has been applied primarily to subassemblies and machined/fabricated parts, such as rotational and prismatic machined items, forgings, castings, sheet metal and plastic items. Hardware items and box dimensions for assemblies have also been coded. CC system usage is wide and includes design retrieval, part family generation, scheduling, cost estimation, equipment justification, computer-aided process planning and general decision making. Company C claims that the system has drastically reduced work time and points to a five-fold increase in design engineering productivity.

4.4. Company D

Company profile. This relatively small manufacturer of packaging equipment, with 406 employees and sales of $30 million, implemented classification and coding in 1986. (The database used to identify firms for our survey indicated Company D as a firm having over 500 employees. Company D responded to the survey mailing, and was found to have fewer than 500 employees. Clearly, the database record for this company's employment level was in error. However, since it was found to be a large-scale CC user, it was included in our subsequent in-depth study.)

Selection/justification. In an effort to cut costs and increase competitiveness, the president established a task force, with members from all company functions, charged with finding methods to increase the firm's viability in the marketplace (Desai 1981, describes a similar cross-functional task force at the Owatonna Tool Co.). Company D had 50,000 active parts and another 240,000 parts which may be activated at any time. Furthermore, 1000 new designs were being added each month. Company D decided CC could address the part proliferation problem. Part standardization and simplification, design retrieval, and part family generation for cellular manufacturing were applications conceived for the CC system.
In choosing a system, Company D considered both OIR and Brisch Birn. OIR demonstrated their system on-site, but this was rejected for its cumbersome (too many digits) coding structure and its high cost. The Brisch Birn system was also rejected as being too costly. In addition, both systems required hardware support not available in-house and did not come equipped with the part number cross-referencing capabilities Company D desired. After reviewing these two vendors and considering information collected from trade journals and seminars, a consultant (a former Brisch Birn employee) who offered a simple coding scheme fitting Company D's needs at about one-third of the 'big' vendor cost was retained. The consulting firm's installation experience was investigated, with previous customers providing payback and operational data. Company D's economic justification was non-traditional, with the primary consideration being the strategic capabilities of the CC tool bounded by some acceptable cost limit.

**Implementation experience.** An eight-digit code was devised so that the first five digits have a monocode structure (Wemmerlöv and Hyer 1985), while the remaining three digits uniquely describe the entity itself (like a part number). All 50,000 raw materials, purchased parts and fabricated items were manually classified and coded and later partitioned into 3500 families. In one case, 18 different part numbers and 11 different part names were found for one part. Some part families had duplication rates approaching 50%.

This project resulted in a less than 1 year payback derived primarily from part duplication reduction. Specifically, the first year of operation showed $140,000 in savings reflecting benefits gained from eliminating 2900 part numbers, discontinuing 950 setups and avoiding 543 purchase orders. In 6 months, 900 h of engineering and drafting time were avoided.

One unexpected benefit arose: customer service for non-stocked parts has improved because Company D could find and rework a stocked part from the same part family (similar examples are provided in Hyer and Wemmerlöv 1989). Company D applied commodity coding (Smolik 1983) to hazardous materials and is systematically eliminating unnecessary ones. Also, the CC system provided a common language for the company and set a base for part simplification and standardization. Computer-aided design and computer-aided process planning capabilities will be integrated into the now fully computerized system. All sub-assemblies and end-items will be coded, and a goal of reducing total part count to 15,000 has been set. Company D advises other manufacturers to consider CC but warns that a great deal of effort is required for successful selection and implementation. They felt that due to their thorough planning and implementation, 'no real surprises' occurred.

4.5. Company E

**Company profile.** Company E, a lawn equipment manufacturer, keeps track of over 33,000 active part numbers to produce 200 end-items.

**Selection/justification.** The firm has a simple, in-house developed CC system for machined parts and hardware items such as fasteners, belts, pulleys, and bearings. This system was put in place in 1986 to test the merits of a classification system and to set the foundation for a full-scale commercial system. It was to be used for design retrieval,
part family generation, and part standardization. In addition, the system was to aid in plant layout decision-making, equipment justification, and product cost estimation.

In 1988, after carefully considering several commercial systems, CimTelligence was chosen for implementation. This package would allow the expansion of the CC realm and add much desired computer-aided process planning capabilities. Company E employed a formal economic justification procedure that met an internal rate of return of 30% and projected an 18-month payback. The intangible, strategic motivation 'to stay competitive in the marketplace' played a role in developing support for the system.

Company E relied on quantitative information from a variety of sources, including trade and academic literature, seminars, and a new employee. Literature data stating percentage savings for various manufacturing applications were applied to Company E's environment. Other companies played a key role in Company E's data collection process. For example, one company's CC justification report was acquired and studied. A sister company of Company E's, who is a user of OIR, also provided information, and a CimTelligence user allowed on-site observation. One company passed on a report comparing performance aspects of OIR and CimTelligence that had been put together by yet another manufacturer. CC vendors provided company contacts who gave insights into system operation, benefits, implementation requirements and planning. The OIR, DCLASS and CimTelligence systems were all seriously considered. DCLASS was considered acceptable but required too much programming to support its detailed tree structure methodology. OIR was rejected due to its hard code structure and its coding format which requires that many questions be answered one by one. Among the reasons that CimTelligence was chosen was its pending adoption of a relational database management system and its general flexibility. The CimTelligence system does not use codes. Instead, users retrieve items by relying on English-like sentences based on a standard query language (SQL). Both design engineering and manufacturing engineering needs could be met with the CimTelligence system which allows different computer input and output screens for each application area.

Implementation experience. The production manager was quite supportive of GT but many of the engineers needed to be convinced of its value. Apparently, this was not easy. Company E, based on experience with its pilot system, advises that CC is 'a great tool' but requires someone with considerable product know-how to implement it. In addition, a firm should do its 'homework in advance' by analysing the company's products and part mixes, and determining the firm's objectives and requirements. Finally, sufficient time must be allocated for implementation, and the CC system should be managed by a staff. (It should be noted that the CC acquisition was approved but temporarily delayed because management, in the face of limited funds, decided to purchase machine tools instead).

4.6. Company F

Company profile. Company F is a producer of forgings primarily for defence and aerospace applications. Made from diverse materials including tungsten, aluminium and steel, forgings are shipped as is or after being machined. Parts forged range in weight from 4lb for missile and engine rings to 300,000lb for space shuttle casings. Approximately 3000 items are produced in lots of 1–300.

Selection/justification. Company F once used a manual coding system to support cost estimation (bid preparation) purposes. The part codes included both shape and
manufacturing process information but provided limited search and retrieval capabilities. Other problems included inconsistent updating of part information and avoidance of the system by certain cost estimators who preferred to rely on their memory for bid preparation data.

In the early 1980s Company F investigated the Air Force TechMod program which provides funds for modernization of defence-related firms. In 1983 funds were granted for initial study of three technology modules, one of which was information systems (including GT and CIM). One engineer went to several CAD/CAM and GT seminars, and then pushed, in vain, for immediate consideration of a GT implementation. Not until the head of the cost estimating department also attended a seminar was GT actively supported. As an engineer stated, one 'needs the right people to get involved to get any real movement'. In addition, he says the TechMod program was the de facto CIM project champion because it provided much of the funding required, while reducing the risk for Company F.

OIR demonstrated their product in-house in 1984 but since Company F had no clear sense of what exactly they required, no acquisition was made. In 1986, after significant learning, a CIM implementation was seriously considered. Discussion ensued whether the GT/CIM system should be manual or computerized and purchased or in-house developed. Company F determined that manual systems could not meet their requirements. Computerized systems considered were CimTelligence, Deere Tech Services, General Electric, DCLASS, and OIR. After listing all desired capabilities and features of a GT/CIM system, Company F had lengthy discussions with OIR, DCLASS and CimTelligence. These talks were followed with questionnaires sent to each vendor requesting detailed responses about particular system capabilities.

A consultant pushed DCLASS and a PC-based system was installed in early 1987, enabling hands-on exploration of GT capabilities. Every 12th part was coded, as were certain 'unique and important' parts. Over 150 parts were coded in total for this pilot project. In operation no similar parts were found, system response was slow and mass updates took over 1 h. Company F felt DCLASS' tree structure was overwhelming and unnecessarily time-consuming to code. In addition, DCLASS could not accommodate storage of exact data, a feature Company F required. Although its performance was below expectation, the DCLASS implementation provided an opportunity for Company F to demonstrate GT to various departments and gain feedback regarding potential applications. Users were enthusiastic about the project, presumably because they were all given exposure to potential benefits. Only the head of industrial engineering was against it.

An OIR demonstration was seen at a user location, but was unimpressive not only because the system crashed but also because it was considered too expensive. A set of parts was brought to the CimTelligence vendor site for a 3-day workshop where CRT data input screens were developed, and parts and process plans loaded. Company F felt that these tasks were relatively easy with the CimTelligence package.

By September 1987, Company F prepared a cost justification for a full CimTelligence system as part of a larger TechMod proposal. The TechMod programme requires that cost justifications place special emphasis on savings areas and amounts. Savings data, stated in percentages, were generated from trade and academic literature and industry technical reports. Many CC system users had also been contacted. Several had experience with more than one vendor product. Most provided substantial anecdotal information on benefits, unexpected applications found, staffing requirements, number of users supported, response times and process plan sizes. While
such information was valuable, these users had not closely quantified the savings achieved. Company F projected a 1.2-year payback based only on the $350,000 to be directly incurred by it. This included $250,000 for a new computer and terminals and $100,000 for software. Costs such as staff time, training, and database loading were not included. The new system could operate on existing hardware, but it was felt that to ensure the rapid system response needed to gain user acceptance, a dedicated, high capacity computer would be required.

Implementation experience. CC was first applied to their primary reusable tooling, namely dies. Dies have large bases in which an impression is cut. Should an impression 'wear out', and if the die base height is adequate, an impression may be cut deeper into the die. Called 'sinking the die', this avoids a substantial retooling cost. The CC system facilitates information retrieval on die availability and modifiability.

Much of the required information is located in a historical database subsidiary to the primary parts production database. This historical database includes inspection and process comments gathered over time. Company F has found that when a production problem arises on the floor for some part, they can look at rework history for similar parts and sometimes find problems rooted in tooling used or processing methods employed. Efforts are being made to provide more historical data on-line because most problems that arise for a product have occurred before. Users need only to document these problems/solutions and search for this information. Controls over data entry and access are being implemented to guarantee data integrity and security.

Company F provides 600 cost estimates to customers every month, and the cost estimation department is a heavy user of the CC system. The materials department searches to see if different materials might work for the same product. The inspection department uses the system to investigate quality problems among similar parts. The order engineering group uses CC for process plan retrieval and printing. In short, GT/CC is used by 'every department in the system—we see it as a plant-wide thing'. There are now over 100 system users.

Company F states it is finding new uses every day and can save some users a couple of hours of time per week simply by adding a field or attribute to the database to meet their needs. However, several system concerns exist. No incentives to use the system are in place, and it is difficult to measure system usage, much less proper system usage. Finally, political problems have arisen over who is responsible for data entry and maintenance.

5. Former coding system user

Company profile. Company G, a $100 million manufacturer of paper-producing machinery, implemented an OIR CC system in 1982, yet discarded it 3 years later.

Selection/justification. The president recognized the merits of the OIR system and was convinced it was needed to stop part proliferation. The CEO and vice-president for administration then championed the system as a vehicle to standardize parts and reduce part variety. Company G gained information on GT/CC from trade journals, seminars and the vendor who provided substantial training and justification assistance. A formal economic justification used payback criteria.

Implementation experience. This system was pushed top-down. While the design engineering department had some enthusiasm for CC, the manufacturing engineering department did not. In particular, the manager of manufacturing engineering was never
convincing of the system’s potential benefits. Nonetheless, it was purchased and implemented. The design engineering department coded parts for 2 years, using all 32 digits of the OIR code structure. This resulted in a difficult and time-consuming coding process. The designers found some limited value from CC system usage, but the system ‘fizzled’ without the support of and usage by manufacturing engineering, where it was felt the greatest benefits existed. The president recognized ‘the error’ of pushing the system top-down and let the system die out. Recently, a new vice-president for manufacturing has restructured the staff and replaced several managers. Newer managers describe some department heads of that time as ‘narrow-minded’ individuals who did not communicate.

The design engineers could have adopted a shortened OIR code structure after their two years of coding to utilize some of the invested effort, but chose not to. Since then, design engineering has been using a method they call ‘alpha-coding’ to reduce part proliferation. This method uses part descriptions that contain key words and information (Ex: GEAR-SPIRAL-HELICAL No. of TEETH). This system has not been tried by manufacturing engineering. Instead, qualitative part descriptions and process experience are used to find part families for numerical control program development and machining.

The current VP-Manufacturing admits it would be very useful to have all parts coded, but is not fully convinced that an elaborate 32-digit CC scheme is necessary. Also, achieving a fully coded part database would be very costly. At one point he considered reimplementing CC, but decided to put emphasis instead on modernization of outdated machine shop facilities. He felt that bringing in flexible, state-of-the-art machine tools was more important than GT.

6. Findings and analysis

This section provides a cross-case analysis of the six current CC system users and (to a limited degree) the system-discard case. The methodology for case study research and cross-case analysis is well described by Yin (1984, p. 13) who states ‘case studies are the preferred strategy when “how” or “why” questions are being posed, when the investigator has little control over events, and when the focus is on a contemporary phenomenon within some real-life context’. While the multiple case methodology is relatively uncommon in operations management research (as are empirical approaches in general), several authors have recently reaffirmed its appropriateness and power for exploratory and descriptive purposes which may lead to subsequent theory building (Flynn et al. 1990, Meredith et al. 1989).

6.1. Firm characteristics

Information about each of the six CC system users is provided in Tables 1A and 1B. With the exception of Company D with 162 workers, user companies employed between 450 and 928 direct labour. Four clustered in the range from 450 to 600 direct labour. Total number of employees at each plant ranged from 406 for Company D to 1950 for Company F, with an average of 1193. Of the four firms that provided annual cost or profit centre information, only Company D (with $30 million in sales revenues) was not in the $210–340 million range (revenues if profit centre; costs if cost centre). These figures are along the lines of Hyer and Wemmerlöv’s (1989) GT respondents who had average sales revenue of $207 million and average employee level of 778.
Five of six users were from the machinery (SIC 35) category, with Company F from the fabricated metal products (SIC 34) category. Further stratified, three companies were from the farm and garden machinery categories (SICs 3523 and 3524) and one each were from special industry machinery (SIC 3554) and general industrial machinery (SIC 3569). Machinery producers, and manufacturers with similar characteristics, appear to have the highest propensity for CC usage (also see Hyer and Wemmerlöv 1989). These manufacturers produce product lines with similar products and relatively standardized parts.

Each company produces multiple end products, with Companies A and B making variations of one end product. With the exception of Company F, all firms produce assemblies. The average number of parts in an assembled end-item gives a sense of the part magnitude at a given company (disregarding the existence of part commonality). This number ranges from 600 to over 2 million. Another perspective is provided by considering the number of purchased and manufactured parts in the inventory database. Again with the exception of Company F, and Company B for which data were not available, all companies have tens of thousands of, and up to hundreds of thousands of, active part numbers (these figures are similar to those found in Hyer and Wemmerlöv 1989).

In general, based on the technologies they have adopted (Table 2), these six companies appear to be technologically experienced. All six use computer-aided design (CAD). Five use production cells while the sixth, Company F, considered but rejected cell use due to the nature of their product (forged, single parts, typically with little machining required). Production cell usage, in three of the five cases, included employment of flexible manufacturing systems. All six companies were users of NC machine tools and statistical process control. Five were material requirements planning (MRP) system users, with only Company F being a reorder point user (again, this firm produced only single parts). Only two firms currently use computer-aided process planning (CAPP), but three more expect to do so in the future.

6.2. CC system selection

**Systems.** Two recent system installations (Companies E and F) are both based on CimTelligence products. The other recent installation, by Company D, was developed in-house with consultant support but based on the Brisch Birn coding structure. For these more recent installations, typical vendors considered include DCLASS, OIR and CimTelligence (in the case of Company C, the existence of a commercial system provided by another division likely precluded a search for alternative systems). In all three cases, DCLASS was rejected due to high cost of programming to implement its tree structure, even though it is intended to make use of already existing databases. Similarly, in all cases OIR was considered expensive. In addition, OIR’s long, complex coding structure was not favoured. Company D, the smallest of the firms studied, initiated in-house development to avoid the hardware requirements of the vendor packages and to cut costs to one-third of vendor prices. These comments are consistent with those of Hyer and Wemmerlöv (1989) who found that primary decision criteria included software availability, ease of assigning codes, hardware requirements and cost.

Both of the oldest installations (Companies A and B) and one newer installation (Company D) are based on Brisch Birn coding schemes. Company B hired Brisch Birn Associates to design a classification and coding structure for their company while
<table>
<thead>
<tr>
<th></th>
<th>Company A</th>
<th>Company B</th>
<th>Company C</th>
<th>Company D</th>
<th>Company E</th>
<th>Company F</th>
</tr>
</thead>
<tbody>
<tr>
<td>SIC number</td>
<td>3554</td>
<td>3523</td>
<td>3523</td>
<td>3569</td>
<td>3524</td>
<td>3462</td>
</tr>
<tr>
<td>Product made</td>
<td>Paper-producing machinery</td>
<td>Farm tractors</td>
<td>Farm and lawn equipment</td>
<td>Packaging machinery</td>
<td>Lawn equipment</td>
<td>Forgings</td>
</tr>
<tr>
<td>Direct labour</td>
<td>928</td>
<td>500</td>
<td>600</td>
<td>162</td>
<td>450</td>
<td>500</td>
</tr>
<tr>
<td>Total labour</td>
<td>1491</td>
<td>860</td>
<td>1800</td>
<td>406</td>
<td>650</td>
<td>1950</td>
</tr>
<tr>
<td>Profit/cost ($)</td>
<td>250 M (profit)</td>
<td>340 M (profit)</td>
<td>N/A</td>
<td>&gt; 30 M (profit)</td>
<td>N/A</td>
<td>210 M (profit)</td>
</tr>
<tr>
<td>Number of end products</td>
<td>Engineered to order</td>
<td>N/A</td>
<td>243</td>
<td>50</td>
<td>200</td>
<td>3000</td>
</tr>
<tr>
<td>Single parts/assembly</td>
<td>Assembly</td>
<td>Assembly</td>
<td>Assembly</td>
<td>Assembly</td>
<td>Assembly</td>
<td>Single</td>
</tr>
<tr>
<td>Total number of manufactured parts</td>
<td>250000</td>
<td>N/A</td>
<td>12000</td>
<td>40000</td>
<td>13000</td>
<td>1750</td>
</tr>
<tr>
<td>Total number of purchased parts</td>
<td>120000</td>
<td>N/A</td>
<td>46000</td>
<td>20000</td>
<td>20000 +</td>
<td>0</td>
</tr>
<tr>
<td>Average number of purchased parts in end products</td>
<td>600 K–1M</td>
<td>5600</td>
<td>500</td>
<td>200–400</td>
<td>65%</td>
<td>0</td>
</tr>
<tr>
<td>Average number of manufactured parts in end products</td>
<td>1.5 M–6 M</td>
<td>2400</td>
<td>100</td>
<td>600–1000</td>
<td>35%</td>
<td>1</td>
</tr>
<tr>
<td>Technologies used†</td>
<td>CM, CAD, NC, CAPP (var), SPC, AGV, MRP</td>
<td>CM, FMS, CAD, NC, SPC, MRP, Robotics</td>
<td>CM, FMS, CAD, CAPP (gen), NC, SPC, Robotics, AGV, Kanban, MRP</td>
<td>CM, CAD, NC, SPC, MRP</td>
<td>CM, FMS, CAD, NC, SPC, MRP, Robotics</td>
<td>CAD, NC, SPC, Robotics, ROP</td>
</tr>
</tbody>
</table>

† CM Cellular manufacturing  
FMS Flexible manufacturing system  
CAD Computer-aided design  
NC Numerically-controlled machines  
CAPP Computer-aided process planning (variant or generative)  
SPC Statistical process control  
AGV Automatic guided vehicles  
MRP Material requirements planning  
ROP Reorder point materials procurement

Table 1A. Large-scale CC system users—company profiles.
<table>
<thead>
<tr>
<th></th>
<th>Company A</th>
<th>Company B</th>
<th>Company C</th>
<th>Company D</th>
<th>Company E</th>
<th>Company F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Use significant part numbers also?</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>For part families?</td>
<td>No</td>
<td>—</td>
<td>—</td>
<td>Yes</td>
<td>No</td>
<td>—</td>
</tr>
<tr>
<td>System purchased or in-house</td>
<td>In-house</td>
<td>Purchased</td>
<td>Purchased</td>
<td>In-house</td>
<td>Purchased</td>
<td>Purchased</td>
</tr>
<tr>
<td>Notes</td>
<td>Used consultant, based on Brisch Birn</td>
<td>Purchased from Company C's Sister Division</td>
<td>Consultant hired</td>
<td>Currently using CimTelligence, used small system for 2 years</td>
<td>Recent implementation</td>
<td></td>
</tr>
<tr>
<td>System age (years)</td>
<td>15</td>
<td>10</td>
<td>5</td>
<td>2</td>
<td>2</td>
<td>&lt;1</td>
</tr>
<tr>
<td>Company satisfaction with system</td>
<td>Very high</td>
<td>Very high</td>
<td>Very high</td>
<td>Very high</td>
<td>High</td>
<td>Very high</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

† Applications included: Computer aided process planning (CAPP)  
  Design retrieval  
  Cellular manufacturing (CM)  
  Non-cellular manufacturing  
  Standardization of parts  
  Equipment justification  
  Product cost estimation  
  Manufacturing scheduling  
  Computer-aided design (CAD)

Table 1B. Large-scale CC system users—systems used/application areas.
Companies A and D hired other consultants to implement a Brisch Birn style system. There seems to be little difference between their methodological structure. It is interesting to note that the old systems are based on Brisch Birn, which was widely available at the time, while newer users are taking advantage of new vendors with more advanced software. As with all computer-based systems, the software continues to improve with time, and firms seem to be explicitly considering system scope and potential upgradeability when selecting CC systems (also see Hyer and Wemmerlöv 1989).

System objectives. CC systems were implemented with the express purpose of design retrieval in all six firms (see Table 1B). For five of the six firms, part standardization was also a reason why CC was chosen. Three companies acquired CC to support cost estimation and manufacturing scheduling. For Companies C, D, and F, CC/GT was part of a large management information system. Only three of the six companies acquired CC for use in cell design — this may confirm the finding by Wemmerlöv and Hyer (1989) that there is a low propensity for using GT codes to establish manufacturing cells.

Pilot projects to aid justification. A number of the companies initially installed a small coding system to gain a sense for CC system benefits and costs. Company E put in place a small in-house-developed system for raw materials before deciding to purchase a full system. Company F employed a PC-based DCLASS system before installing a large-scale system, and recommends spending $5000–10000 on a prototype system prior to full system purchase. Company B did a sampling study before full-scale implementation and recommends that potential users conduct such pilot programmes and studies. Company A also used existing small-scale coding systems as an entry into full CC. The advantages of a small trial system include:

1. sets a foundation for larger systems;
2. allows hands-on experience;
3. provides insight into and supports experimentation with classification schemes;
4. helps develop CC system selection criteria;
5. is a starting point for discussion with potential user departments on CC system capabilities and their respective needs, leading to better system design;

<table>
<thead>
<tr>
<th>Technology</th>
<th>Number of users</th>
<th>Usage rate (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Computer-aided design (CAD)</td>
<td>6</td>
<td>100</td>
</tr>
<tr>
<td>Cellular manufacturing (CM)</td>
<td>5</td>
<td>83</td>
</tr>
<tr>
<td>Flexible manufacturing systems (FMS)</td>
<td>3</td>
<td>50</td>
</tr>
<tr>
<td>Computer-aided process planning (CAPP)</td>
<td>2</td>
<td>33</td>
</tr>
<tr>
<td>NC machine tools (NC)</td>
<td>6</td>
<td>100</td>
</tr>
<tr>
<td>Robotics</td>
<td>4</td>
<td>67</td>
</tr>
<tr>
<td>Automatic guided vehicles (AGVs)</td>
<td>2</td>
<td>33</td>
</tr>
<tr>
<td>Material requirements planning (MRP)</td>
<td>5</td>
<td>83</td>
</tr>
<tr>
<td>Reorder point systems (ROP)</td>
<td>1</td>
<td>17</td>
</tr>
<tr>
<td>Pull systems (KANBAN)</td>
<td>1</td>
<td>17</td>
</tr>
<tr>
<td>Statistical process control (SPC)</td>
<td>6</td>
<td>100</td>
</tr>
</tbody>
</table>

Table 2. Technology usage by the six large-scale CC users.
(6) motivates other departments to 'buy-in', reduces resistance to change;
(7) provides a basis for cost and benefit data gathering;
(8) demonstrates CC system value to top management;
(9) proves to all that the system works (or does not);
(10) helps assessment of software/hardware requirements and potential for systems integration;
(11) gives a sense of the magnitude of the implementation and coding task;
(12) assists in identification of most promising parts categories (those entities having high redundancy, similarity, or usage), and prioritization of subsequent full-scale coding activity.

Similar thoughts are expressed in Hyde (1981), Hyer and Wemmerlöv (1985, 1989), and Gallagher and Knight (1986). In particular, Hyer and Wemmerlöv (1989) and Gallagher and Knight (1986) refer to selection and design of a coding scheme as an iterative and continuous process where experience with a code gives insight into where system and code expansion or modification is necessary. Hence, pilots can be of value for gaining this experience early.

Other data sources. All companies gained information from vendors, and five looked to other companies for a mix of operational and anecdotal data. Five gathered information from trade publications and three gained knowledge from academic literature and courses/seminars. The types of information gained included CC system cost/benefit data, operational insights, and implementation strategies. See Table 3 for a summary of information sources used to support CC system selection and justification.

6.3. Justification

Procedures. The capital justification procedures for all companies except Company D generally followed traditional methodologies and company guidelines. Payback and/or internal-rate-of-return criteria were used, and all showed projected payback of less than 2 years. To support the economic analysis, several companies gathered savings data from trade and academic literature (such as Hyde 1981, Hyer and Wemmerlöv 1989), internal analyses and pilot projects, other companies, vendors and seminars (Table 3). Each firm derived data from multiple sources, except for Company D.

<table>
<thead>
<tr>
<th>Source</th>
<th>Benefits</th>
<th>Costs/resources</th>
<th>Number of firms using this source</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Quantitative</td>
<td>Qualitative</td>
<td>Quantitative</td>
</tr>
<tr>
<td>Vendor</td>
<td>A-F</td>
<td>A, C, D, F</td>
<td>A-F</td>
</tr>
<tr>
<td>Consultant</td>
<td>F</td>
<td>D, F</td>
<td>F</td>
</tr>
<tr>
<td>Trade journals</td>
<td>A, B, D-F</td>
<td>D</td>
<td>B, D, E</td>
</tr>
<tr>
<td>Academic lit.</td>
<td>E</td>
<td>D</td>
<td>E</td>
</tr>
<tr>
<td>Courses/seminars</td>
<td>A, D, E</td>
<td>A, D</td>
<td>E</td>
</tr>
<tr>
<td>Other companies</td>
<td>B, E, F</td>
<td>D, F</td>
<td>B, D-F</td>
</tr>
<tr>
<td>New employees</td>
<td>E</td>
<td>none</td>
<td>E</td>
</tr>
<tr>
<td>Other: Pilot projects and sampling studies</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 3. Data sources used for cost/benefit estimations by companies A–F.
C which relied entirely on its sister division that was the vendor. The firms complained that hard savings data do not readily exist, particularly in their industry areas. Five firms also listed and emphasized intangible factors without quantifying them or explicitly integrating them into the justification models (see also Desai 1981). For example, Company F's justification report emphasized the following intangible factors:

- Improved communications through common vocabulary
- Increased capacity of existing equipment
- Increased process planning productivity
- Individual expertise knowledge capture
- Improved responsiveness to customers
- Improved sales forecasting/marketing projections
- Reduced throughput time
- Standardization in process plans, designs, terminology
- Increased process plan and estimate accuracy
- Reduced time for engineering changes
- Reduced cost of quality
- Reduced raw material requirements for tooling
- Increased productivity on a plant-wide basis
- Reduction in setup times

Only Company D discarded traditional justification methods, instead looking for a system with the necessary features at lowest cost. The strategic aim 'to stay competitive in the market' provided overriding support for the system acquisition. Hyer and Wemmerlöv (1989) note that four (of 33) CC users did not consider cost a factor in influencing their acquisition decision.

**System intangibility.** In the system-discard case (Company G), CC benefits were acknowledged recently, but the costs of renewed usage were seen as daunting. Instead of CC, they chose to install new manufacturing equipment which has lower risk of failure, higher payback, more tangible results and less organizational disruption relative to CC. In a somewhat similar situation, Company E delayed purchase of a CC system so that they could acquire new machine tools. These cases point to the intangibility of information systems which provide only data, and have no value unless the data are used. It should be noted that CC systems can be contributors to fundamental organizational improvement, while machine tools generally simply satisfy shorter-term capacity needs.

### 6.4. Implementation and usage

**Top management support.** In all six cases, top management actively supported the CC installations. Companies C, D, and F all had considerable support for CC installation as a subset of full CIM systems. In each of these cases, selection and implementation was led by a CIM task force, group technology coordinator or CIM manager (also see Gallagher and Knight 1986, Hyer and Wemmerlöv 1989). These people had top management mandate to work across numerous departments. In all cases, CC was seen as a competitive necessity and advantage. Top management support has long been thought critical to CC system success (Hyde 1981, Hyer and Wemmerlöv 1985). Our findings support this notation.

Continued system success requires that top management support be continued as long as CC is intended to be used. This is particularly true due to system maintenance
costs. Company B's diminished management support (apparently as a result of a merger) led to lower staffing levels and reduced system effectiveness. This finding regarding the importance of continued resources is supported by Hyer and Wemmerlöv (1989) who found that four firms (20% of the non-CC users in their GT survey) had abandoned CC, and did so primarily due to resource limitations.

A related managerial issue is that of providing particular incentives so that the system is used, and disincentives so that the older methods are not used. Company F found it quite difficult to even roughly measure system usage, and while interested in creating incentives, does not know what to do. Some firms require substantial paperwork for justification and creation of a new part, which may at least serve as an 'incentive' for usage of CC systems for design retrieval.

The system-discard case failure appears to be due to lack of user support. While management support for CC implementation is required, a top-down mandate may fail if the users are not convinced of its value. The system user must, to some extent, be the champion, so top management support alone is not enough.

Project management. User companies state that the selection/implementation project leader must possess great knowledge of, and insight into, the company's products. This implies that while technical expertise (such as software development and CC methodological skills) might be accessed from outside the company, the project manager must be experienced and from within the firm.

Resultant insights. Hyer and Wemmerlöv (1984) state that users find GT as a way to understand their company and scope of products produced. This study finds similar claims. At Company F, those who were involved in the CC implementation project gained a new understanding of their company, its activities and its process flows. One concern is whether this new understanding is widespread, or only among those involved in selection and implementation.

High payback item groups. Each company chose to first code those item groups that provide quickest (tangible) payback due to part duplication elimination or high degree of retrieval need. Helle (1989) suggests an alternative selection rule—first code those items with longest projected life. Company A first coded raw materials and purchased components. Company B has been the most thorough, claiming to have coded all parts from raw materials to end-items in their tractor division. However, coding has not been consistent company-wide. In Company F's case, tooling was coded first, showing that CC systems can be applied successfully to non-traditional entity groups also. Table 4 summarizes the item types that have been coded across the six companies. In general,
purchased parts and machined/fabricated items are coded with a somewhat greater frequency than raw materials, subassemblies, and end-items. This result deviates from the study by Hyer and Wemmerlöv (1989) where the coding frequency of machined/fabricated parts and subassemblies greatly exceeded the frequencies of the other item types. Since firms have different information needs and there are different uses of codes at various stages of production, these discrepancies are likely due to the different composition of the company samples in the two studies.

**Data capture and system maintenance.** Users advise that implementation not be rushed and that a staff be set up and empowered to maintain the system (also see Desai 1981). It appears to be quite important that even before implementation, the data entry group should be established and financially and administratively supported. Company D explains that selection/implementation requires a great deal of effort, but they found no surprises once the system was in place due to their careful planning. The deterioration of Company B's system arises from reduced staffing to keep the entire system up to date. There is conflict within Company F now in determining who should enter part information. While many departments may want to use the information, few care to spend the time and money to perform coding. For the system-discard case (Company G), an issue arose over who should do the coding and why. This firm did not resolve this issue before system implementation. In this case, manufacturing engineering stood to gain a great deal from CC but did none of the coding. Hyer and Wemmerlöv (1989) found several firms where special GT departments were charged with the coding tasks.

The experiences of firms A, B, and G show how difficult and time-consuming it is to keep the CC system up to date (continued entry of new parts). This is particularly true for complex parts. Such problems can prevent data from being captured in a disciplined way, creating incomplete databases (as seen in Company G). Data capture is not only expensive (Wemmerlöv 1990)—it is likely to be a tremendous hindrance to CC adoption and maintenance if data capture is excessively time consuming and if database searches have low 'hit' rates (successful retrievals). This finding confirms Gallagher and Knight (1986), and supports Hyer and Wemmerlöv's (1989) study which found that database creation and maintenance was a formidable task for a number of CC users. The end result is that usage can drop off as maintenance falls.

In the system-discard (Company G) case, it appears that an overly elaborate coding scheme was used, causing user dissatisfaction. Company G would potentially have achieved great gains via a simpler coding structure. We believe the cost and effort of data capture and maintenance are the greatest obstacles to CC system adoption.

**Upgrading.** Given that computing technology changes over time, CC users sooner or later inevitably desire improvements in system characteristics such as response time, ability to store different types of data elements, etc. However, switching to a new system, or in some cases making major modifications to existing systems, requires a great effort and sometimes a whole new data capturing activity. Companies A and G were unwilling to undertake such new systems projects due to data capture and maintenance reasons. Company A continued using its old system while Company G simply discarded its system.

**User-friendliness.** Ease of use in terms of data input (screen generation and coding), system response, and reports generated, was very important for all companies. In short, it was felt that the greater the user-friendliness, the lower the risk of project failure.
Company F purchased a new computer to guarantee quick response, believing that users must be satisfied with the system from the first day of implementation for it to be successful. We certainly agree with this line of thinking. CC systems are often criticized for slow response times due to large databases and inadequate computer support (also see Hyer and Wemmerlöv 1989). It is not cost-effective to risk the success of the CC project and its longevity because of improper computing assistance.

**Breadth of usage.** Companies C, D, and F see CC as a company-wide activity, while in other companies, usage is limited to certain departments. This limitation seems to come about for several reasons: lack of continued management support for system growth; user resistance; poor communication between departments; and inability/unwillingness to code all items. At Company A, many parts were not coded due to part complexity, while at Company B staffing and communication problems have limited CC's widespread use. This finding of limited use conflicts with Hyer and Wemmerlöv (1989) who found that in all CC usage cases more than one functional area employed coding, even though breadth and depth of usage varied greatly across companies.

The cases also show how difficult it is to capture data relevant to both design and manufacturing. This is evident for firms A, B, and G where the manufacturing engineering departments were not frequent users. Interestingly, Hyer and Wemmerlöv (1989) show that it is the manufacturing engineering set of applications that tends to exhibit the most impressive performance. CimTelligence's feature of having screens that can be adapted to individual classes of users is a step towards supporting usage by multiple organizational functions.

**System integration.** In Companies A, C, and F, the CC system is integrated with other computer-based applications. Typically these applications are oriented towards materials planning and cost control, such as order entry, materials ordering, and costing systems. Two of the systems are integrated with CAPP.

**System dynamics.** The early installations and systems were focused on part retrieval, part standardization, and part variety reduction (as seen in Companies A and B). Newer systems have more capabilities, both in their ability to capture information (as seen with Company F's capture of historical information in verbal form), and in their capabilities as database systems with support programs (like CAPP). Thus, we see a shift to broader user applications over time and a more varied set of part types coded (as seen in Companies C, E, and F). When Companies A and B looked for commercial systems, there were not many alternatives beyond Brisch Birn. Later users have had more alternatives to choose from (though admittedly not many—this is a highly limited market with respect to competitors).

Company D, due to its in-house system, is an exception here. Nonetheless, the Company D situation shows that simple, in-house developed systems can be quite powerful although they have limited capabilities.

7. **Conclusions**

This paper described and analysed CC system implementation and usage by six users and one former user. We found that the current users were generally quite satisfied with their systems, that traditional capital justification procedures had been used in most cases to support system approval, and that CC implementation and usage are not simple tasks. Certain managerial guidelines emerged: systems should be user-friendly; systems can be purchased if items to be coded are of a standard variety;
considerable top management support is required and must continue through the life of the system; system maintenance is critical, and should be the responsibility of a specially designated staff; pilot programmes can be of great benefit in aiding system selection, justification and design; and 'high payback' part groups should be coded first. A major lesson is that the decision to implement a CC system cannot be taken lightly. Once acquired, it must be maintained and kept current to provide value to the firm. Also, it can be very costly to change to another system or to substantially modify the existing system.

For these reasons, it is important that classification structures meet application objectives, and are flexible so to support future product mixes, new product and process technologies, and database integration. At the same time, codes should be as short as possible since long, complex codes require great data collection efforts and greatly reduce ease of use. The ability of more recent systems (which do not use codes) to store exact part attributes in relational databases greatly increases flexibility and ease of use, but does not reduce the importance of deciding what data should be captured.

Certain research questions emerge from the cases. Only three of the six CC users employed CC to aid in design of manufacturing cells; however, GT/CC has long been thought critical for this application. This lower than expected application rate should be investigated. Possible reasons may be that other cell formation techniques are more easily applied, or that CC users need further education with respect to this application.

New CAD software which can support direct 'classification' from CAD databases via graphical attributes of the part raises an interesting issue—to what degree is the classification task minimized due to this automation of the data capture process. If CAD capabilities do greatly reduce data capture and maintenance costs, CC becomes viable for many more firms. On the other hand, problems arise regarding appropriate graphical standards and attributes, and potential limitations on data capture to only design (not manufacturing or other) attributes. This is a relevant technical research area.

GT/CC has long been mentioned as a means for supporting efficient and effective product design, and takes on a heightened relevance due to the contemporary emphasis on rapid new product development. In particular, many of the tools and techniques (including quality function deployment and design-for-assembly) used to facilitate and enhance the development process are information intensive (see Rosenthal and Tatikonda 1992). An important research question is how CC systems, with their codified and classified data on parts, process equipment and other entities, could support such tools and techniques.

High and low payback part groups must be determined for various manufacturers. In addition, whether all parts in a part group must be included in a GT database should be understood. There is a critical tension pitting database completeness with resulting high hit rates vs expensive data capture for complex parts that have very low probabilities for subsequent retrieval.

Understanding which part groups have higher payback than others clearly specifies a sequence of data capture activities and new CC applications. Research on this issue would involve development of a methodology for auditing system usage and effectiveness over time. We need to know what factors most effectively foster organization learning, and in particular what impact the computing technology plays. Also, the ability to assess CC system dynamics would lead to structuring appropriate incentives for system usage, determining relevant performance measures, generating more reliable cost/benefit data, and gaining improved means for user feedback. In
addition, such research would provide a better sense for appropriate structuring of the initial system implementation to maintain flexibility in light of potential future needs.

Finally, if the data from the survey discussed in section 3 are representative for the mechanical industry at large, CC system usage is not widespread. Sixty per cent of the survey respondents did not use CC, and only one-third of the remaining respondents used a CC system that was not highly limited in application. The low CC usage may be due to several reasons:

1. lack of understanding of the cost of redundancy, time spent on searches, avoidable inefficiencies, and the costs of complexity in general;
2. incomplete understanding of CC/GT;
3. the intangible nature of information system benefits;
4. low perceived up-front benefits;
5. fear of not being able to maintain system discipline over time;
6. cost of data capture perceived to be too high relative to system benefits;
7. adequate or acceptable systems already in place;
8. organizational inability to implement CC.

We believe the CC/GT database can be an important part of a computer-integrated design and manufacturing system. The challenges of CC selection, implementation and usage are both managerial and technical. Accordingly, further research in both areas is needed. Past usage-oriented research on CC relied primarily on firms' self-reported data (via surveys, interviews). Future research should include both longitudinal studies and real-time observation of CC selection/usage to greatly increase our understanding of the operational issues in, and costs/benefits of, CC systems.

References
GT classification and coding case studies


