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GROUP TECHNOLOGY IN SYSTEMS INTEGRATION

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ABSTRACT

Systems integration (SI) requires that components must be thoroughly analyzed, simplified, standardized and optimized over its lifespan to achieve true integration. Group technology (GT) provides a rational framework for integrating systems. GT is a disciplined approach of grouping parts, process, equipment, tools, people, information, energy or subsystems based on similarities and optimizing their efficiency and effectiveness over time. It involves attribute identification and family formation, classification and coding, simplification, standardization and optimization. Family formation, classification and coding are the cornerstones of group technology. We have established that GT is a science-based concept which has many potential applications for simplifying, standardizing and optimizing complex systems. Design guidelines on how to effectively carry out GT are given. Specific research and development trajectories are suggested.

Keywords: System Integration, Group Technology, Attribute identification, Classification and coding, Standardization, Optimization, Family Formation, Cellular manufacturing

INTRODUCTION

Combining complex systems of components, parts, tools, equipment, people, information, energy and of systems themselves into functionally efficient and effective integrated whole has become a major challenge and research arena for industrial engineering. Today's systems have become more complex and more varied. Systems of today consist of more elements resulting in fuzzier relationships between them. Integrating components with ill-defined relationships has become more difficult. Automation has been offered as one solution. However, simply automating systems without the benefit of a genuine process of systems integration is expected to result in suboptimum performance and waste of resources. To achieve true integration, systems components have to be thoroughly analyzed, simplified, standardized and optimized over their lifespans.

Systems integration (SI) is the optimization of all components comprising a system over time. SI is a dynamic design improvement approach anchored on the concept of synergism. Synergism means that the behavior of the component parts depends on the objective and the behavior of the whole. It is a formal hierarchical methodology of determining the best configuration of systems components which gives the best measures of performance over time. SI aims to achieve ***continents*** of excellence and discourages ***islands*** of excellence.

Shunk (1985) [48] states that there are three ways of truly integrating systems. These are integrating the information system, integrating the control systems and integrating the material flow systems. Group technology (GT) is one of the most often discussed and proposed framework for integrating these systems. [48].

Group technology is considered as one of the technical building blocks of systems integration. It is a concept of grouping based on similarities of certain systems attributes or characteristics. It is a very simple technology which combines similar activities together, simplifies and standardizes closely-related items, stores and retrieves information in the most efficient manner. It can be defined as a disciplined approach of identifying and analyzing attributes or characteristics of systems, components, parts, processes, equipment, tools and people, grouping them into families according to similarities and subsequently optimizing their performance and effectiveness over time.

In the face of increasing complexities in the structure and behavior of systems brought about by pressure for world class performance in quality, productivity, responsiveness and robustness, the need for an efficient analytic framework for systems integration has become critical.

The main object of this paper is to describe and examine the applications of group technology in effecting systems integration. Specific GT application areas are discussed and compared. Implementing and adopting GT is likewise discussed. Specific research trajectories are suggested.

EVOLUTION OF GROUP TECHNOLOGY

It is reported that the formal concepts of group technology were originated by Soviet scholars in the 1940's and 1950's. [48]. In 1959 S.P. Mitrofanov, a Russian, published a book entitled ***Scientific Principles of Group Technology*** which described GT as a ***method*** of manufacturing piece parts by classifying these parts into groups and applying to each group similar technological operations. The aim was to achieve economies of scale in jobbing and batch production normally associated with large-scale production. Organizing manufacturing via group technology was originally proposed by Mitrofanov. [37]. The focus of Soviet GT was the reduction of set-up times via sequencing of similar items and development of ***composite components***. Composite components were hypothetical parts which represented the set-up needs of a group of similar items. [37].

In the 1960's, GT spread to Eastern and Western Europe. In particular, West Germany and Great embarked on serious studies on GT techniques. In 1963, the Soviet Union legislated the increased implementation of GT in Soviet industry [52].

GT studies in Europe stressed the development of GT classification and coding system. Foremost of this was the Opitz System [38].

In the early 1970's, Japan had begun sponsoring GT applications while in the United States widespread acceptance started only in the latter part of the decade. In the same period, in Western Europe, the use of manufacturing cells or GT cells became popular.

In the 1980's GT has metamorphosed into a broad-based efficiency philosophy encompassing all its previous definitions and interpretations. [65]. By this time, most industrialized countries have made references to GT applications.

In the present time, interest in GT has grown and has become widespread. Its popularity has revolved around the introduction of the just-in-time (JIT) manufacturing philosophy and the growing acceptance of systems integration as an area of concern.

Figure 1 shows the evolutionary epochal period of GT development.

GT METHODOLOGICAL APPROACH

By exploiting sameness and eliminating unnecessary variety, GT can reduce complexity. Embedded within GT are the concepts of simplification, standardization and optimization.

The initial step in GT is to define the system of interest. The intended application and uses must be clearly understood. The objectives must be defined and the level of aggregation clarified.

The second step is to identify attributes and form family of similar characteristics. A family is a collection of items that share certain characteristics found relevant for a particular purpose and where the difference within the family are smaller than the difference between family and non family members (Wemerlov, 1990 [57]). Family formation is a process of identifying multiple attributes and selecting items from a large population that fit the characteristics required for a specific purpose.

Attribute families can be formed either by informal or formal methods. Informal methods create families based on an ad hoc manner while formal methods are based on classified and stored information about item characteristics. Informal approaches may rely on visual appearance (e.g., shape or surface finish), mechanical or functional characteristics (e.g., strength of material), memory or item name.

Formal methods of family formation consist of relying on significant part numbering system, classification and coding systems and attribute data systems. A significant part number (SPN) is a part number that contains some intelligence about the item to which it has been assigned.

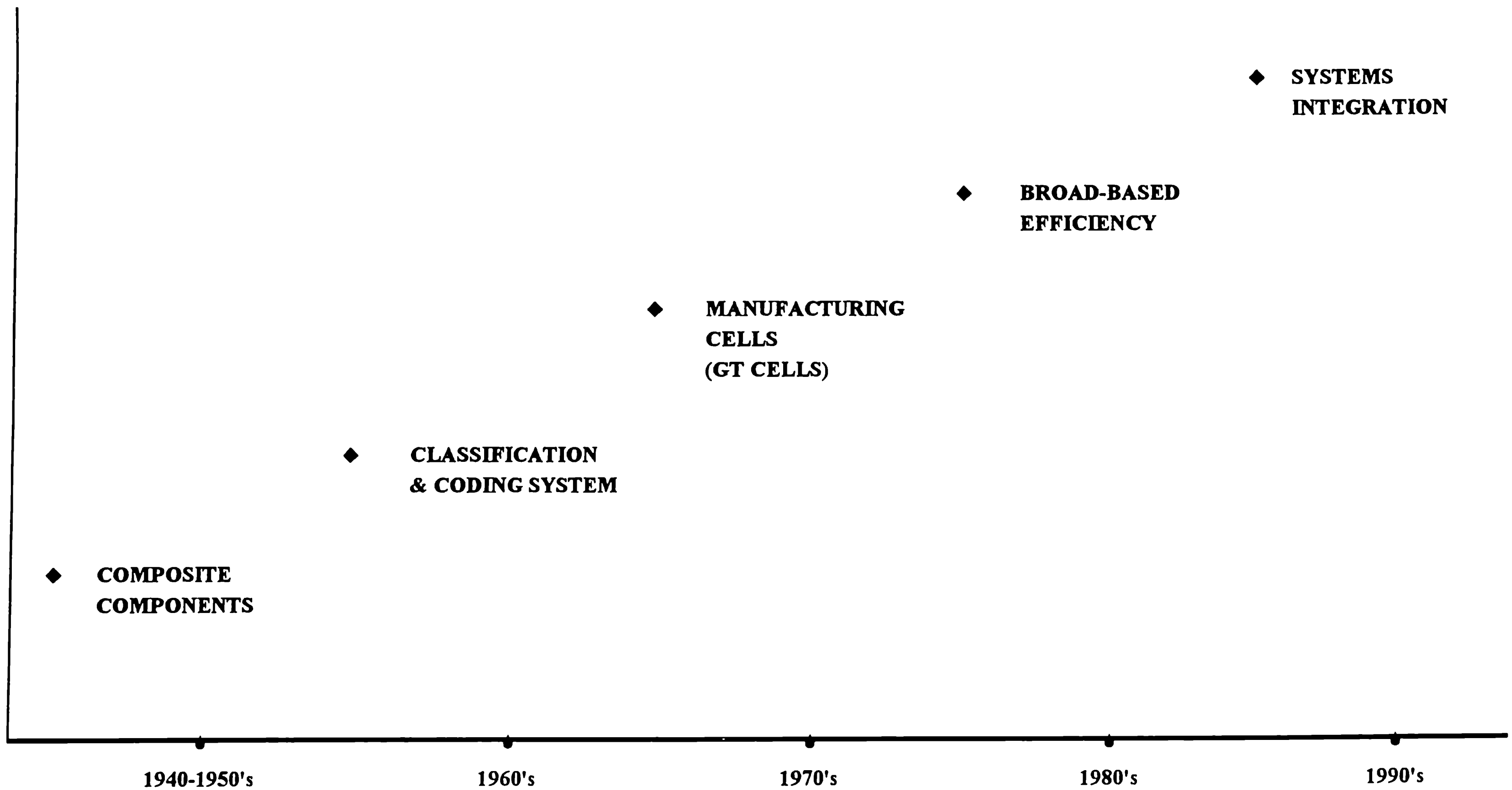


Figure 1

EVOLUTION OF GROUP TECHNOLOGY

In manufacturing systems, part families can be formed by ***(a) direct observation; (b) design features; (c) production features; and (d) production flow analysis.***

The third step is to classify and code the attribute characteristics. Classification is the assigning of an item to a class. A class is a group of items which have at least one similar attribute. The purpose is to group together similar items and differentiate among dissimilar items. Coding is the assigning of symbols to the item. A code is a set of symbols used for capturing and conveying information. Classification structures the attributes into intelligent clusters while coding assign a specific symbol digit or letter to a particular attribute of the item.

Attributes can be captured either by fixed assignment or by variable assignment. In a fixed assignment, attribute is captured in a distinct fixed format. With variable assignment, classification ***trees*** are constructed hierarchically. Basic information are categorized into finer and finer detail.

The fourth step is to simplify and standardize. The purposes of simplifying is to reduce unnecessary variety and improve control of information and its uses. Similar parts are combined and given the same code. Duplicates are eliminated. The end result of simplification is to come up with an ***ideal*** set of ***standardized*** options. After simplification standardization follows standardization consists of selecting the ***best*** attributes and commonizing their characteristics. The purpose is to establish discipline in using the items within the standard range. These twin activities can also be integrated in the classification and coding step.

The next step is to develop and prepare the computer software for the GT system. The development of the software should consider the availability of commercially available GT softwares. A ***make*** or ***buy*** decision has to be done. In the development or choice of the GT software, the following costs need to be considered: [57].

(a) *Installation costs*

- *hardware (CPU, disk spare, terminals)*
- *software*
- *software customization*
- *installation*

(b) *Training costs*

- *Managers*
- *Systems Manager*
- *Users*
- *Data entry personnel*
- *Materials and Manuals*

(c) *Data capture costs*

- *Data entry personnel*
- *Reproducing drawings*

(d) *Operation costs*

- *System personnel*
- *Resuming training*
- *Resuming data capturing*
- *Software maintenance upgrades*
- *Hardware maintenance*
- *Integration with other systems*

The preparation of the GT software should include implementation and the training of personnel who will use the software. It should consist of deciding on data categories and how they will be stored in the system, customization of screen pages and forms, actual capturing of data and loading of system, testing and tracking of results and monitoring progress against implementation plan.

The next step is to use the GT system for the intended application whether it be in design, manufacturing, operation or control. A critical activity in this step is to routinize the GT application procedure.

Figure 2 depicts the flow chart of group technology approach.

ATTRIBUTE IDENTIFICATION AND FAMILY FORMATION

The identification of attributes is the basic foundation of group technology. System attributes can pertain to the objective, to the environment, to the functional characteristics, to the structural properties, to the manufacturing or processes involved or to any feature of the system where similarity can be exploited.

As described earlier, attributes can be physical properties, functional characteristics, production or manufacturing processes. To discern similarity, it is necessary to critically search through these various characteristics. The ability to recognize similarity is very critical in identifying attributes.

From the attributes identified, families can be formed. Similar items can be grouped into families. Forming families can be done in many ways. However, regardless of the method used in forming the family, it is important to meet the requirement of the most or highest number of similarities for the family.

CLASSIFICATION AND CODING SYSTEM

Classification and coding formally captures, labels and stores attributes. It is the heart of group technology. The primary purposes of classification are to reduce variety, minimize storage and retrieval time, simplify and standardize parts and process and increase productivity, quality and utilization.

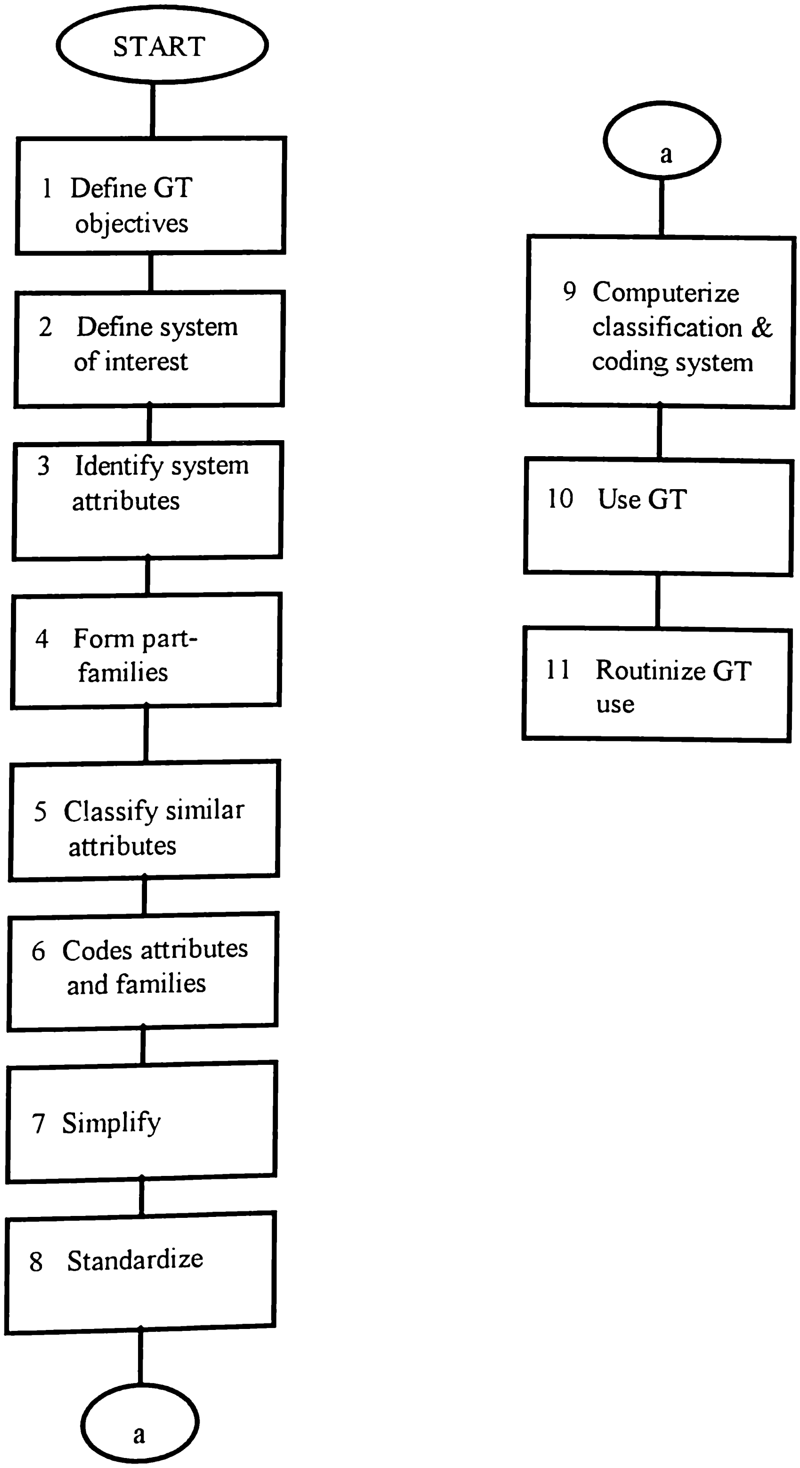


Figure 2. Group Technology Flow Chart

A coding system provides a vehicle for the efficient recording and retrieval of relevant, information about items. The most popular coding symbols are the digits of the number system and the letters of the alphabet.

There are three basic coding structures used in classification and coding. These are the monocodes, polycodes and the mixed-mode code.

A ***monocode*** is also known as a hierarchical code. In this code, the meaning of each character is dependent upon the value of the preceding character. For example if digits are used as symbols, the meaning of each digit depends on the value of the previous digit. The main advantage of a monocode is providing large amount of information in a relatively small number of digits especially when there are diverse parts or components. A tree structure can be used to depict the coding system. However, when the tree become large and many branches have few classification settings, the monocode becomes inefficient. Figure 3 shows an example of a monocode.

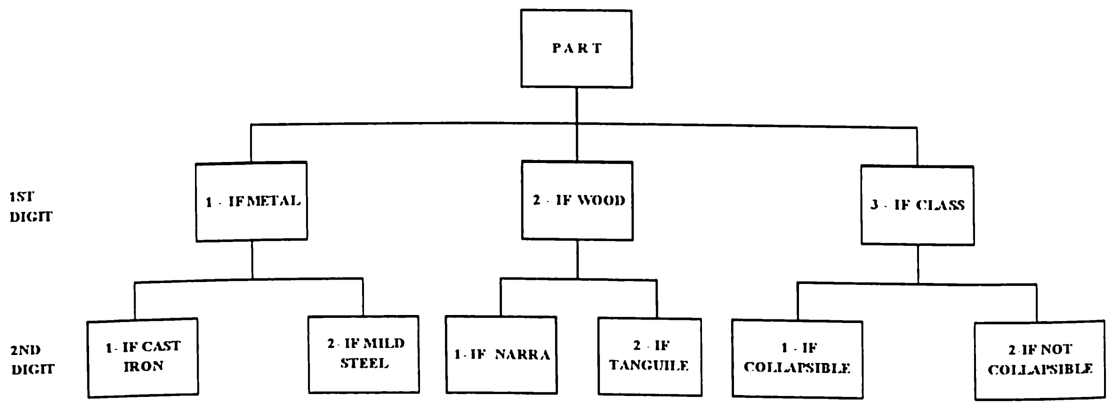


FIGURE 3. Monocode Example

A ***polycode*** is also known as an attribute code, a chain code, a discrete code or a fixed digit code. The meaning of each digit is independent of any other digit. Each attribute can therefore be assigned to a specific position in the code. Attribute codes are advantageous for cases where parts have similar features. However, when parts do not fit easily into attribute categories, the resulting code may become unreasonably long. Figure 4 presents an example of a polycode.

A ***mixed-mode code*** is a mixture of the monocode and polycode that allows dependence and independence in the same string of digits. With polycode, the advantages of the monocode and the polycode are combined. Polycodes are used for information which needs to be accessed

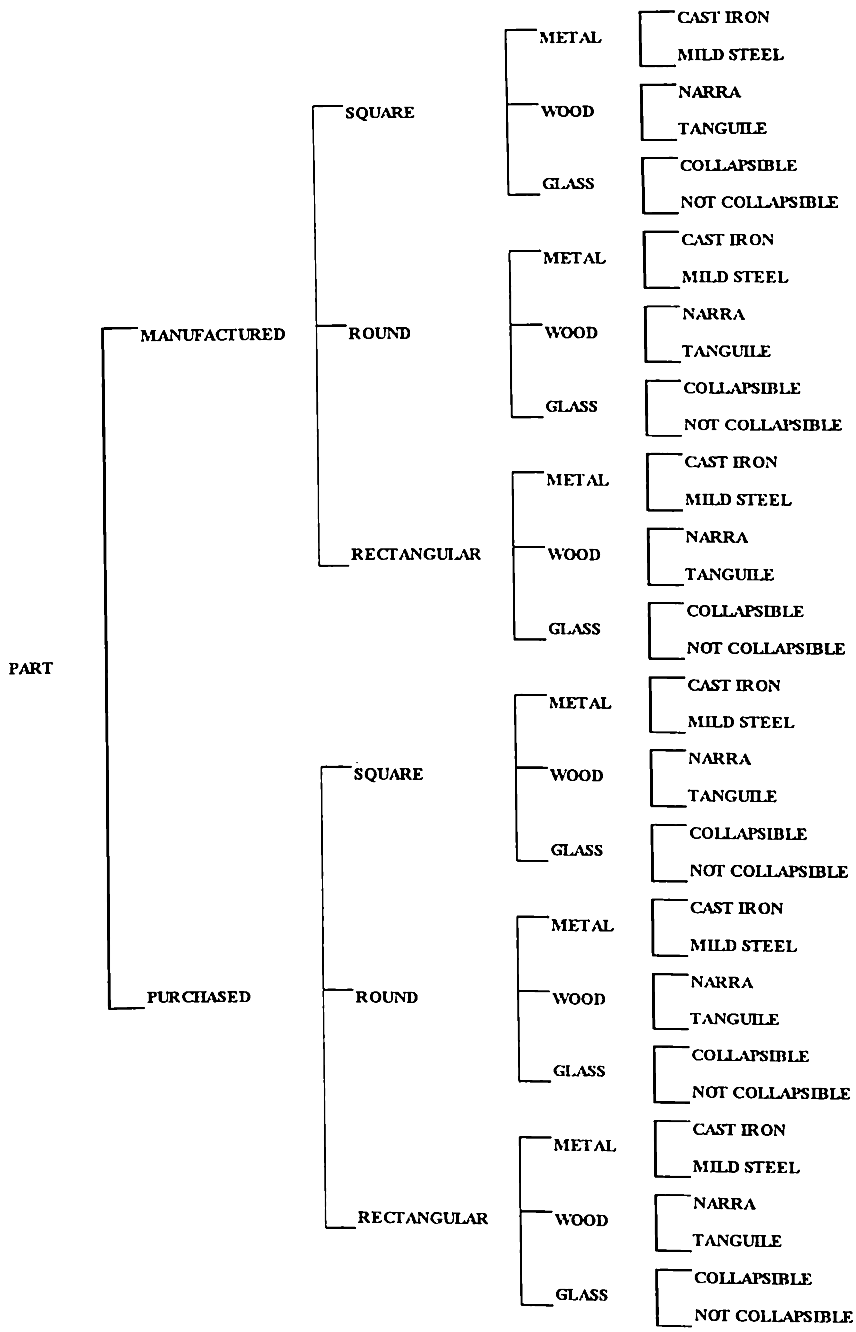
1st DIGIT	*2nd DIGIT*
• 1 IF METAL	• 1 if cast iron
• 2 IF WOOD	• 2 if mild steel
• 3 IF GLASS	• 3 if narra
	• 4 if tanguile
	• 5 if collapsible
	• 6 if not collapsible

FIGURE 4. Polycode Example-

frequently whereas the monocodes are used for information which is unique to a subclass of items and where the alternative number of alternatives is large. Figure 5 illustrates an example of a hybrid code.

In developing or choosing a classification and coding system, the following criteria should be considered: [57]

1. *Objective of the system*
   - Is it for variety reduction?
   - Is it for design retrieval?
   - Is it for simplification and standardization?
   - Is it for manufacturing producibility?
   - Is it for combination of the above purposes?
2. *Robustness*
   - What are the part attributes and applications? (Table 1 provide some sample attributes and their associated applications)
   - What are the future applications?



1st Digit	2nd Digit	3rd Digit	4th Digit
(source)	(shape))	(material type)	(material name)
1. manufactured	1 - square	1 - metal	1 - cast iron
2. purchased	2 - round	2 - wood	2 - mild steel
	3 - rectangular	3 - glass	3 - narra
			4 - tanguile
			5 - collapsible
			6 - not collapsible

POLYCODE MONOCODE

Figure 5. Hybrid Code Example

3. *Simplicity*

- Is it easy to use?
- Is training minimal?
- Is it costly to use?

4. *Efficiency*

- How many digits to use?
- Is the number of digits sufficient?

5. *Automation*

- Is there a need to automate?
- What computer hardware to use?
- What database method to employ?

6. *Cost*

- What is the initial cost of the system?
- What are the operational and maintenance costs?
- What are the interfacing costs?

There are two basic approaches in coding and classification: ***universal classification systems*** and ***specific classification systems***. ***Universal classification systems*** are for general applications irrespective of industries, companies or products while ***specific classification systems*** are custom-made or tailor-made for a specific application.

It is reported that there are more than 100 GT classification and coding systems which are commercially available [57]. Some of these most common classification and coding systems are briefly described below:

(1) **Brisch System (United Kingdom)**

The Brisch system is a specific classification and coding system tailor-made for a particular application. This system is basically design-oriented, well-suited for design, component retrieval and variety reduction. It has a primary code structure of 4 to 6 digits depending on the items to be classified and the customer requirements. A secondary code can be added to cover additional classification requirements such as shape and other production information.

(2) **Opitz System (West Germany)**

The Opitz system is a universal system useful for design retrieval and group technology application. The system consists of 9 digits. The first 5 digits, called the geometrical code classify the form of the component while the remaining 4 digits called the supplementary code represents the dimensional ratio, material, original shape and accuracy of machining respectively. It is considered as a compromise between the requirements of design and production.

(3) **Vuoso System (Czechoslovakia)**

The Vuoso system is a universal system aimed at studying workpiece statistics and selection of families for GT applications. The system used 4 digits, 3 of which are hierarchically arranged in classifying shape including size and proportions. The fourth digit has fixed significance. It defines the component material. It is simple and less detailed than the Opitz method.

(4) **KC-1 System (Japan)**

The KC-1 system is a simple universal system developed in 1967 by the Mechanical Engineering Laboratory and Small Business Promotion Corporation of Japan. Its code structure consists of a 5- digit decimal system representing shape, dimension, processing method, material and accuracy.

(5) **DCLASS (Design and Classification Information System) (United States)**

DCLASS was developed at Brigham Young University. This system is used for education and research purposes and for prototype development. The DCLASS part family code comprises of 8 digits partitioned into 5-code segments. The first segment composed of those digits devotes the basic shape. The second segment devotes the form features, the third segment devotes the size, the fourth segment devote the precision while the last segment devote the material type.

DCLASS is a universal classification system.

(6) **MICLASS (Metal Institute Classification System) (Netherlands)**

MICLASS was developed by the Netherlands Organization for Applied Scientific Research. MICLASS consists of two sections. The first section is a 12-digit code which is used to classify the engineering and manufacturing characteristics of a part: main shape, shape elements, position of the elements, main dimension, ratio of the dimension, an auxiliary dimension, tolerances and materials. This section is mandatory.

The second section is optional. It can contain as many as 18 characters tailored to meet the specific needs of a company such as vendor, lot sizes, costs and productivity tips. The first 12 digits are universal.

MICLASS is a universal classification and coding system which include several computer programs capable of performing data management, design retrieval, and production mix.

(7) **C O D E [] (United States)**

CODE: The Parts Classification Data Retrieval System for Computer-Aided Manufacturing was developed by the Manufacturing Data Systems, Inc., USA. It is an 8-digit hybrid code which can be expanded to 12 digits. Each position of the code can have one of 16 characters (0 through 9 and A through F). When CODE is expand to 12 digits, the additional digits may be used for attributes such as heat-treat, hardness, finish, material, production cost, and time standards.

There are many other GT classification and coding systems developed over the last 20 years. Part Analog System by Lovelace, SAGT by El Gomayel, CUTPLAN by Metcut, et al., CIMTelligence of the Organization for Industrial Research (OIR), Multi-CAPPIL, another OIR creation, and the Deree's System by John Deere are some of these systems available. For more detailed information about them, the interested reader is referred to [11]. [34]. [39]. [51]. [53]. [54]. [57].

Guidelines for developing GT classification and coding systems were recommended by Wemerlov (1990) [57]. The list includes.

(a) Clearly identify goals for the coding system.

(b) Organize information before beginning to structure the code.

(c) Standardize terminology.

(d) Involve eventual users early in code design and development.

(f) Make sure every symbol serves a purpose.

(g) Capture only important information.

(h) Do not make categories so general that they obscure meaningful differences or so narrow that like items are not in the same class.

(i) Make the code flexible by leaving areas to expand.

(j) Do not build in information easily accessible elsewhere.

(k) Computerize coding and retrieval if possible.

(l) Code only permanent features.

(m) Keep the code system simple.

(n) Do not agonize over the 1% that will not fit.

The advantages and benefits of a well-designed GT coding and classification system can be summarized as follows: [3].

1. Efficient retrieval of similar parts.
2. Effective product design data.
3. Design standardization and variety reduction.
4. Formation of part families and machine groups.
5. Design productivity.
6. Effective computer-based process planning system.
7. Rational production planning and scheduling.
8. Accurate cost accounting and estimation.
9. Standard routings for part families.
10. Increased utilization of equipment, tools and people.
11. Improved NC programming and effective use of NC machines.
12. Improved plant layout.
13. Effective purchasing and procurement of materials.
14. Lower costs.
15. Improved quality.

While GT classification has numerous benefits and advantages, it has also several disadvantages. Among them are:

1. Installing a GT classification and coding system can be expensive.
2. there are no accepted technology standards.
3. Resistance to change may be encountered.

GT APPLICATIONS

Described below are some of the most important application of GT.

GT Applications in Design

The main objectives of GT application in design are to prevent future design proliferation, reduce existing part population, and increases human productivity in the creation of new designs and the revision of old designs based on previously designed parts. Specifically, effective implementation of GT in design is expected to reduce time to create new designs, reduce number of unnecessary items, part numbers, stored designs, new designs per year, number of design errors, and time required to retrieve an existing design. With GT design, product designers and manufacturing engineers work concurrently to make logical decisions based on manufacturing data about specific part attributes. Actual performance of parts with similar attributes supplement product reliability much faster.

GT Applications in Manufacturing

Machine component grouping is one application of GT in manufacturing. It involves finding the families of similar parts and forming the associated groups of machines. Three of the methods used for machine-component grouping are the ***Production Flow Analysis (PFA), the Rank Order Clustering Algorithm (ROC)*** and the ***Single-Linkage Clustering Algorithm (SLC). Production Flow Analysis*** was developed by Professor J.L. Burbridge and consists of three levels of analysis: ***factory flow, group analysis*** and ***line analysis. Factory flow analysis*** determines and simplify material flow system. This is done by dividing the plant into departments and allocating space into these departments. ***Group analysis*** determines the processing of component parts into group while ***line analysis*** finds the sequence of machines which approximates the line flow.

The ***rank ordering clustering algorithm*** is ideal for production flow analysis. It is designed to generate diagonalized groupings in machine-component matrix. ROC was developed by King [60].

The ***single-linkage clustering algorithm*** defines the similarity coefficient between two machines or operations divided by the sum of components visiting both and either of the two machines or operations. Machine grouping is obtained constructing a dendrogram from the matrix of pairwise similarity coefficients [60].

Another GT manufacturing application is tooling and fixture set-up. With GT tooling, set-up time can be drastically reduced. Using group tools and fixtures, one set of tooling can be provided for each part family. Equipping machines with rapid exchange mechanisms and pre-set tool holders can allow very rapid tool set-up. With the use of ***composite*** components, many unnecessary operations or tools for manufacturing can be eliminated. In addition, the use of jigs and fixtures for multiple uses simplifies work arrangements and set-ups. The use of the ***key machine concept*** for creating the most important manufacturing cells can increase utilization of there most critical equipment.

GT can optimize the process planning process. Shunk (1985) [48] described GT process planning as a sophisticated generative system in which more intelligence is captured in a GT knowledge base which optimizes the process plan and the finite available capacity standardization of process plans requires the identification of families of similar parts, determination of standard plan for each family, assignment of a standard plan for each family, modification of a standard plan and the elimination of the old plans. [48]. Two forms of computer-assisted process planning (CAPP) exist. [57]. *Variant* and *Generative*. *Variant CAPP* is a system which can execute searches of a database and provide the user with a library of standardized forms and strings of words that can be printed on these forms while *Generative CAPP* is an approach where the logic used by the process planner is sorted in a computer code. [57].

GT simplifies production control and scheduling. Group production control concentrates on the control of the overall workload and withdraws from detailed progress chasing. The migration from functional layout or cell layout eliminates unnecessary material movements and increases throughout time. GT makes materials requirements much simpler. It provides MRP systems with detailed production routing and bill of materials for whole families or parts thereby reducing the amount of data to manipulate.

GT also provides purchasing support. In a purchasing environment, with a rigorous GT system all related parts can be identified, organized, simplified and standardized. Easily, similar parts can be grouped, duplicates eliminated and group procurement implemented thereby saving on repetitive ordering, excessive inventory or unwarranted shortages.

GT in Cellular Manufacturing

Cellular manufacturing is a group technology application for manufacturing process consisting of manufacturing cells. A cell is a collection of ***dissimilar*** machines or processes located closely together and dedicated to a set of ***similar*** products or parts. [65]. The main purpose is to improve efficiency by simplifying processes and the production of similar parts. Aside from reducing more distances and times between work stations, the cell serves as a socio-technical unit where operators in a cell work together to produce more or less compete output rather than isolated single operations.

Manufacturing cells can be distinguished by the operations performed in the cells, the degree of labor intensity, and the internal flow pattern. Cells can perform fabrication or assembly operations. A ***product*** cell is either a pure assembly cell or a combination of an assembly and fabrication cell. A ***part*** cell only handles fabricated parts. A ***manned*** cell is one where the cell operators are responsible for part loading/unloading, machine operation and monitoring, tooling exchanges, parts handling, scheduling of parts and simple maintenance while ***unmanned*** or ***automated*** cells are cells with high degree of automation with respect to equipment, materials movement scheduling and tool changes. The ***flow line cell*** is a cell whose flow approximates the straight line as much as practicable. It is very simple, and movement never backtracks. The other extreme is a ***job shop cell*** can have complicated flow pattern.

Non-Manufacturing Applications of Group Technology

Because of the simplicity of group technology concepts, applications of GT extend beyond the manufacturing floor. GT has been applied to commodity and product coding and standardization (e.g., the universal product code (UPC) bar coding, the classification and coding for electronic parts and assemblies). It has been used to classify and standardize equipment and machines. It has been employed to taxonomize mathematical models like the Kendall System of queuing systems. It has been applied to classify and design human resource systems such as the employee number system, the Social Security Number system to name a few. It has been used to categorize data and information. Name a complex system and an application of GT can easily be identified. In fact, the applications and potentials of GT are unbounded. It is even claimed that it is only limited by the designer's imagination.

IMPLEMENTING GT

GT requires a change in mindset. It is important to prepare the organization before it is formally adopted. A progressive approach is deemed superior than a total approach. With a progressive approach, the introduction of group technology proceeds on an incremental basis. By establishing pilot applications, understanding of the GT philosophy and the overcoming of the resistance to change can be achieved easily. With GT successes, it would be easier to convince the skeptics and the non-believers of the actual benefit of implementing GT.

After this initial preparation, the full implementation and routinization of GT should ensue. For example, for a manufacturing situation, GT can be introduced as follows:

Phase I
- Introduce coding and classification system
- Collect production data

Phase II
- Sort and analyze data
- Form machine groups, layout and work schedule

Phase III
- Detail analysis
- Specify machine requirements
- Design group tooling and set-ups

Phase IV
- Set-up standard procedures
- Automate
- Debug and test
- Routinize

CONCLUSIONS AND AREAS FOR FURTHER INVESTIGATION

We have examined group technology as an integrating framework for systems integration. We have reviewed its underlying concepts. We have examined its methodological approach and discussed in sufficient detail family formation and coding and classification. We have also described its many applications and the method for its introduction and implementation. We come to the conclusion that group technology (GT) is a simple broad concept based on the theory of similarities which has many potential applications for simplifying, standardizing and optimizing complex systems. It has a science-based methodological approach which can rationalize and system of interest.

We wish to point out though, that within the local setting, we have yet to find a decent, respectable application of group technology. Even in the manufacturing sector, we are not aware of any documented application of GT. Because GT is very suitable for multi-variety, low volume products, we suggest a formal research study on GT in job shop type small and medium industries. The purpose is to examine cellular manufacturing for boosting productivity in these industries. Initially, we recommend a preliminary assessment of the existing manufacturing configurations in the metal working industry where GT applications are widespread in industrialized countries. MICLASS, OPTIZ or DCLASS systems can be considered as a coding and classification system. Such classification can be very useful in simplifying and standardizing production processes.

Finally, we encourage systems designers to incorporate GT concepts in designing system configurations. While the benefits accruing to GT are enormous, successful GT applications require the skills of an industrial engineer with good understanding of systems engineering.

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