Chapter 2
Practice and Procedures

2.1 Introduction

Author recalls a comment made by his manager in the early 1970s to the effect that “...I wish somebody could tell me exactly how much this part will cost to manufacture...” The machine tool company in the UK where the author was trained and subsequently employed as a Methods Engineer had been in the business of making large vertical turning centres since 1887 [1]. The question arose because we were trying to establish the best possible route to manufacture a certain part and this required access to many strands of information which were in different departments. The practice at the time was that someone did the methods engineering and someone else did the time estimations, costing was done at global levels, hence there was no way of getting at the individual part manufacturing cost, it was too inaccessible.

In more recent times a Blue Book Series 2003 from CASA/SME on ‘Cost Engineering: The Practice and the Future’ makes an interesting comment on the state of art at the beginning of twenty-first century [2] and makes a following remark: “Another area of future growth and research in cost engineering is to capture and reuse human expertise or knowledge used during the development of a cost estimate. This micro-knowledge management will help to analyse an old estimate better before it is reused. The current commercial software needs to go a long way to develop this capability in an intelligent manner so that the additional workload on the cost estimators is reduced.” The basic task of methods engineering is to design the most economical route for part manufacture and assembly. The way the variables are handled and integrated has changed, more through an evolutionary process than a revolutionary one, as a result more transparency is now possible. The overall capability still remains short of the accurate and instant answers required by the professionals to make rapid decisions. The strong need and the immediacy to answer a cost-related question will never go way, after all business is about making profit otherwise it will not survive, we look at the practice and procedures available to assist this process.
2.2 Practice

What is actually involved in part manufacture and assembly planning? What are the variables and how do they interact? What is the nature of costing and is true costing really possible? What roles computers can play and what are the limitations of people involved? We attempt to answer these questions in order to better understand the practice involved.

A methods engineer develops through training and practice an intuitive feel for the processes involved in part manufacture and assembly. When he (he is used in a general sense throughout this monograph to refer to a person) sees a paperclip he perceives all the processes involved, commencing with the feeding of the wire into the manufacturing system, cutting of it to length without influencing the material properties, the bending of it into the required shape without spring-back effect, and the packaging of it into container for delivery, just to mention a few of the macro-tasks involved. On the other hand, when an ordinary person sees the paperclip he sees the form and the function only, he cannot discern the processes involved in its making, just like seeing cooked food but not knowing the process involved in its making. The manufacture of complex parts, such as gears, is such a difficult task that it is a speciality in its own right. This complexity centres on the material properties, the shaping processes, quality and handling attributes, and it is made more complex by volume requirements. This is just for one part, given that there are often many parts in products, the activity of process design soon becomes a demanding exercise and requires procedures to assist it.

The above examples illustrate the fundamental issue in process design, it is that form creates relationships and these relationships have to be management. The correct mapping of these relationships into the data is at the core of process design, and manufacturing knowledge plays an important part in this. The relationship can be one-to-one, one-to-many or many-to-many. A part can be planned by one person who has all the required knowledge, example of one-to-one, a more complex part may require the input of several people, an example of one-to-many, or many different parts may have to be planned by many different people, an example of many-to-many. This creates complexity that soon becomes unmanageable and given that there are also many other relationships that require detailed considerations and things often change unpredictably we end up in a scenario where process design and the management of it becomes a demanding exercise. While the author was carrying out a cost-modelling project in China [3] the vice president of the company involved remarked that even the most predictable cost that of materials has now become seriously unpredictable, because as a commodity it has become part of the futures market, a cost modelling done at certain stage therefore becomes invalid even few hours later. The processing equipment have a value at certain point in time based on their depreciation rates, if this is not correctly accounted for the results will be wrong. Similarly, if a more experienced resource is replaced by a less experienced one
then the costing of part manufacture will be wrong, this leads to some of the
difficulties involved in the costing of manufacture. It is valid at a certain point in
time only, just like a balance sheet, and this point of time is often different from
that when the part is actually manufactured and assembled. It may appear
therefore it is an intractable problem and at best we can live with the estimates
only. To overcome this requires live or real time relationship among the vari-
ables involved so that they could be manipulated at will and at any time to
provide a snapshot of true cost. This was not possible until the recent time when
low cost computers came along and software capabilities emerged to help
minimise the influence of time.

2.2.1 Methods Engineering

Product design requires planning for manufacture; otherwise it remains an idea
only. This planning is the genesis of process design and it has been there from the
beginning when industrial manufacture commenced in earnest. The metals-based
mass manufacture commenced at the onset of twentieth century and led to the
development of methods engineering discipline. Prior to that manufacture was a
craft-based activity and an individual often carried out all the processes involved
to produce the product. He manufactured all the parts and then assembled them
and had all the procedural knowledge required, which was often gained through
long apprenticeship. There was no need for him to communicate his knowledge,
the procedure existed in his mind only and he continuously improved it through
practice. The mass-manufacturing activity changed all that and created the need
for communication of process design to others, this was the beginning of the
practice of process design. A 100 years on we are still grappling with the com-
plexities involved, particularly in the formalisation of process knowledge and its
communication.

In the beginning communication of process design knowledge was via
sketches and they depicted the actions involved, this method was easy to
understand and is still in use today, you only need to look at self-assembly
instructions of a product. This approach worked well for assembly because to
describe the process involved would be unbearably lengthy, this is not the case
in part manufacture. A drawing or a sketch of part is the starting point, what is
required after that is the description of steps and the tooling involved. This led
to the evolution of methods sheet [4] which records the sequence of events as a
narrative. The development of this narrative and the interpretation of it require
great deal of manufacturing knowledge and this led to the discipline of
Methods Engineering. This discipline has served well for over a century to
assist the manufacture planning. The methods sheet captures the process
knowledge, therefore much effort went into its development. We look at the
procedures that evolved from it.
2.3 Procedures

2.3.1 Constructive Method

The nature of form is complex, it can be made up of straight lines or curved lines, or it can be two-dimensional like a flat sheet, or it can be three-dimensional like a solid casting. These forms require accurate interpretations for manufacturing and this led to the manual approach for process planning. The methods engineer who is familiar with the resource available to carry out the task first examines the drawing of the part in detail and then writes down the steps involved, including the details of machinery and the tooling involved. This leads to a routing sheet for part manufacture and the procedure is called the Traditional Method [4]. With the evolution of computers it became possible to store and retrieve the routing sheet and the combination of manual interpretation of drawing and the utilisation of computers to manage the data led to the Constructive Method [4]. This method became the forerunner of more advanced techniques.

2.3.2 Variant Method

It was inevitable that computers will be utilised to exploit the similarity of parts and this led to the Variant Method [4], it became the cornerstone of what is we now call Computer Aided Process Planning (CAPP). Variant Method exploits the similarity of parts as well as the similarity of processes. This similarity can be on the basis of individual process or it can be on the basis of group of processes. The main disadvantage of this procedure is that the quality of process design still depends to a considerable extent on the knowledge of the methods engineer. There are no inference mechanisms in the procedure to fine-tune the process design. This is often required because there are tolerances and various levels of stresses involved in the manufacture of parts and this requires experience to create a feasible process plan.

2.3.3 Generative Method

Computer-aided automation of process design requires a whole new approach to part manufacture and assembly planning. This centres on the decision logics, formulae, algorithms and data extractions. This approach is labelled as the Generative Method [4]. Examples of such procedures are Decision Trees, Decision Tables, Axiomatic and Expert systems. Regardless of their approach they remain complex in nature and this led to the specific applications, such as those in sheet metal fabrications and electronics manufacture, where parameters are more
confined. The development of computer-aided drawing and solid modelling has now opened up new possibilities for features extraction, but the overall automation of process design remains difficult; this has more to do with the ability to foresee difficulties in part manufacture and assembly than just meeting the requirements of micro-processes.

2.4 Costing

Costing requires process plans as an input and the procedures described above provide for this. Costing activity used to be called cost estimating, but is now generally termed cost engineering [2]. This encompasses other functions such as decision-making and budgeting by predicting the cost of activities, we look at the practice and procedures in this area.

2.4.1 Traditional Approach

Decades ago, products were simple in their design and the number of parts involved was low, this simplicity enabled the costing to be done by an individual and cost-estimating became a specialised area. The cost estimator gained considerable know-how of the costs involved and could give first-cut estimates of new products or family of them in a rapid manner. These first-cut estimates were not far off the mark, later when the detailed design emerged it was possible to validate the cost estimate by examining the nature of manufacture involved. These detailed estimates looked at the activity times and the associated costs and this led to what is called activity-based costing. It is a useful concept because it is based on quantitative analysis and is linked to the hard data on manufacture. The drawback of this concept is that the stage at which this is done is often far too downstream of the product conceptualisation stage, therefore limiting its potential for new product designs. The products of today are very sophisticated in terms of their number of parts and the technologies employed and it has become imperative to know the cost as soon as possible in order to reduce the business risk, this has led to other procedures for costing.

2.4.2 Parametric Approach

The parametric approach utilises the similarities of variables as for example in the building industry. The cost of building is often related to the square metres of surface involved and this means the amount of work and the cost of materials is known from previous experience. Such similarities are valid in most cases because
in the business environment there is much emphasis to minimise the risk. This is achieved by a gradual improvement of design; in other words products from one stage to next involve only incremental change and this can be readily handled. It is generally assumed that the change is linear and the costing can be extrapolated from one product to another, as long as there is a similarity of design. This linearity can be expressed mathematically and utilised in cost engineering. This may appear simplistic but it has certain benefits, for example it is of much value at the product conceptualisation stage, this means an early indication of manufacturing cost is known and this reduces risk.

2.4.3 Integrated Approach

The integration of costing with process design is desirable but often it is not possible. The features based costing provides possibilities, through features the part is described as a sum of standard features such as faces, edges and holes that require manufacturing. The cost of manufacturing a feature is first established and then used across other parts. For this to be effective the manufacturer requires a large geometric database. This presents problems because the definition of a feature is not so easy to standardise across organisation even though it may be manufacturing a similar class of product. To overcome this research effort has turned to neural-networks which are part of artificial intelligence systems. The aim is that computers can learn the relationships involved among the attributes and the costs. In the end analysis we go back to the point made earlier that there are infinite forms to be produced, hence there are infinite process design possibilities, and a heuristic approach becomes particularly attractive in such settings. It is defined as a process that obtains solutions by exploring possibilities rather than by following sets of rules or algorithms. The activity of part manufacture and assembly planning is the interplay of materials, form features, equipment and the task attributes and planner achieves optimisation through intuition and experience and this makes the process akin to a heuristic approach [3].

References

Manufacturing Process Design and Costing
An Integrated Approach
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