Estimation of non recurring costs in manufacturing

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Abstract

This research aims to improve estimation of the non recurring costs (NRCs) of manufacture. Investment required prior to the first unit of production varies depending on the industry. However shorter production runs mean that manufacturing investment levels are increasingly relevant. The larger body of cost estimation research is focused on modelling product unit cost. Much cost estimation practice is informed by experience and understanding of costing relationships. The less frequent development of new manufacturing capacity limits options for research and the development of bodies of expert knowledge in the estimation of NRCs. In the early stages of a project, when accurate estimation of total investment is required, there are few reliable predictive indicators for total NRCs. Yet the importance of NRCs remains that they can significantly impact product unit cost. Unit cost being defined as recurring plus non recurring costs divided by production numbers. When NRC's are at an inappropriately high level compared to the number of products sold, the total recovery of investment, or the breakeven point, can occur damagingly late in a production run. With aerospace production runs often spread over many decades this late breakeven period equates to a "cash-burning" project over an extended period.
The aim of this research is to develop additional competence to estimate NRCs through increased understanding about NRC cost estimating relationships. In this research the estimating practice of aerospace engineers, facing novel build philosophies, has been captured through cause and effect analysis and decision trees, in order to investigate NRC cost structures and drivers of total NRC levels. Concurrent engineering has generated a variety of cost estimating models with the most sophisticated being developed around large volumes of product data. This research will also help develop NRC cost modelling in order to provide a basis for validation of NRC cost assumptions for current product cost models.

Key Words

Non-Recurring, Cost, Cost Estimation, Manufacturing

1 Introduction

All manufacturers must balance the advantages of economies of scale from large volume production with the added value of innovative new products despite their expected shorter production runs. The broad trend is towards more customized products that are readily differentiated in the market place, and which have stimulated concepts such as lean, agile and flexible manufacturing (Harrison 1997). As a result of this trend the cost of generating manufacturing capacity is necessarily being absorbed by fewer units, although mass customisation and product platforms are being used to mitigate the effect. There develops therefore, at the concept stage of a new product, a theoretical breakeven point where the sale of a sufficient number of units has covered the investment in capacity. Only after breakeven is there the potential to generate profit. Non recurring cost (NRC) estimation has traditionally been a secondary activity allied to investment analysis and liquidity issues, with reducing production volumes it becomes crucial that an early indication is gained that breakeven is within a feasible market share.

2 Definition

NRCs have been defined as qualitative design inputs to estimation (Roy, Kelvesjo et al. 2001) but for the purpose of this paper they are considered by the alternative definition of capital expenditure incurred prior to production of the first unit (Curran, Raghunathan et al. 2004). The expenditure can include engineering effort to design and acquire or upgrade systems and tooling but excludes prepayments for materials or supplies that will be part of the recurring costs of ongoing production. The recurring costs are therefore recognisably proportional to the volume of production and would include the costs of supporting production including developing manufacturing processes.
Confusion should be avoided about the use of the term “non-recurring costs” as applied to financial statements in which context it refers to charges to the profit and loss account that will not occur routinely such as for redundancies or reorganisations.

3 Cost estimation implementation - construction.

Most effort in estimating NRC is expended in the construction industry where unique projects combine specific locations with original designs and particular build philosophies. The US Army Corps of Engineers (USACE) range of competence runs from levees such as those that where overwhelmed at New Orleans to stabilisation of hazardous toxic or radioactive waste and includes a wide range of buildings, structures, ports etc. This organisation stipulates two types of cost estimates across its entire operations (US Army Corps of Engineers 1997)

a) Where possible construct a work breakdown structure (WBS) and build up detail as available,

b) Otherwise use parametrics to produce an outline estimate.

The USACE adds predefined contingences for uncertainty as percentages of total cost and these reach 25% for unique design involving extremely complex or innovative technology. At a lower level of description the highest risk is associated with estimating soil excavation and this can reach 55% at the onset of a project. These contingencies can be compared with the 2012 Olympic Games construction where the UK treasury has demanded a 60% contingency to cover uncertainty over the 5 year period 2007-2012.

An interesting perspective on estimation accuracy is given by a paper on the PIREM tool (Yu 2006) , this looks to identify key (principle) item ratios across many construction projects, the tool then works to survey the correct price for a pareto optimum criteria. This strategy is designed to focus on the 20% of most significant costs which generate 80% of the overall value; the ratio estimating method is used to map these costs to overall project cost, hence a good understanding of 20% of the costs can generate an accurate project estimate.

4 Cost estimation implementation – manufacturing

Case studies suggest that the use of WBS as a basis for both NRC and RC estimation is common in manufacturing and this would seem predictable since it is an engineering management tool for modelling production. The way the WBS is populated does seem to vary, in some cases there is adoption of parametric values, in others synthetics (parametric like values determined through analogy rather than statistics) and finally differing levels of definition through supplier provided information is used in bottom up methodologies.

5 Cost estimation research

In a review paper (Roy, Kelvesjo et al. 2001) the authors analyse cost in terms of cost drivers and divide these into qualitative and quantitative drivers while reporting work to better understand Cost Estimating Ratios (CERs). Thus an estimate is a prediction of driver activity based on an understanding of relationships. A review of cost modelling in aerospace (Curran, Raghunathan et al. 2004) proposes a classification into traditional and advanced costing methodologies. It was asserted that the state of the art was analogous estimation (also known as cased based reasoning CBR) and that this was superior for modelling new products. However Curran proposed a new state of the science with a two level abstraction for a genetic/causal theory. This theory based approach would avoid the focus on simply generating an estimate value at the cost of generating and understanding a holistic cost structure, “foundation over function”.
Another review (Layer, Brinke et al 2002) divides estimation into qualitative and quantitative approaches with quantitative models being classified into statistical, analogous and generative analytic. The review has a product focus and sees the role of modelling as enhancing cost determination in the product development

lifecycle; it also concludes that case based reasoning is the superior current methodology. The focus on product cost modelling is maintained in a review by (Niazi, Dai et al. 2006) that repeats the use of a high level division into qualitative and quantitative models which are sub-divided into intuitive and analogous and parametric and analogous respectively. Scanlan, Rao et al. (2006) describe a range of costing tools with a high level classification into parametric and generative tools with generative further sub-divided into rule based, equation based and model based. The use of different tools at different stages as a design moves from concept to detail is described. Work is then reported on a tool (DATUM) that was developed to model unit costs, based on an analysis of the design. The tool is capable of the level of detail consistent with a feature based model and allows tradeoffs between different designs to minimise cost.
More advanced model collaboration has been indicated by the patent application process, with proposals to use an NRC optimisation model with a predictive marketing model. The origin of the cost/learning curve is adjusted by NRC to allow the nth aircraft to intersect the future demand at an acceptable cost, figure 1. The NRC investment can be increased to an optimal level where reduced cost of the first units and hence the cost/learning curve origin (moving from curve A to B) allows the intersection of future units with a predicted market segment.

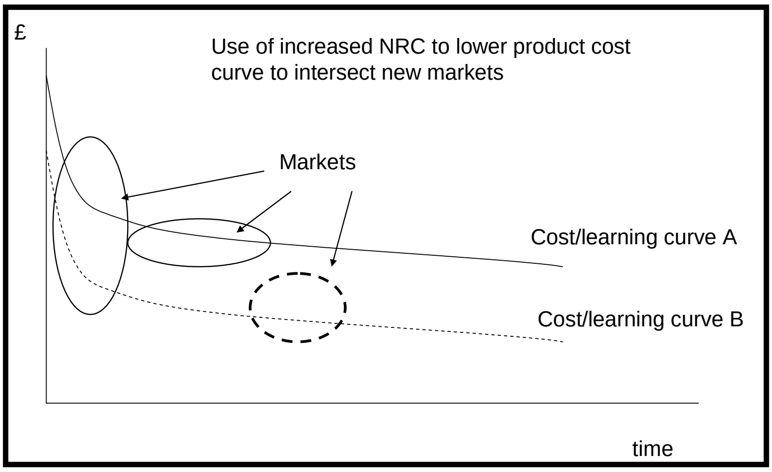

Figure 1 Visual Interpretation of benefits of combining models.

The conclusion from this survey of reviews is that there is a strong focus on manufacture on the use of product cost models and methods or tools in order to produce unit cost estimates. There is little evidence of models that are specifically designed to model manufacturing NRC. This reveals a further issue, in that there is no evidence that the depreciation allocation by product focused models has validated NRC assumptions. It is indicated that the use of different estimation methods for NRCs throughout the development of the product design will produce better estimates. Also indicated is the value of fitting the estimation strategy, i.e. which methods are used when, to the particular case (case based reasoning) especially given the novel nature of the estimation challenge for new capacity.

6 NRC - models, focus competences and interaction.

Current work by the authors of this paper, proposes that the criteria which would distinguish NRC models from production (RC) models is the key conceptual drivers in the modelling assumptions, the production model is driven by volumes and larger volumes should generate lower costs. The NRC model would by contrast be driven by rate, the capacity to produce being additionally defined by an attribute modelling through time.
Additional challenges to the RC model come from its assumptions of effort profiles, the implied idea that a project will be executed according to an idealised schedule. The NRC model would be more likely to accommodate project slippage through its response to rate requirements.

7 Proposed modelling strategy

This research does not adopt a single method of estimation, it understands that decisions are required about which methods may be suitable and which drivers of cost need to be considered at different stages of design maturity. Modelling these decisions and supporting them is proposed as a way to develop the additional estimation competences required. Buckley, J, et al. (1976) propose a classification of business decisions with the highest level (and a desirable characteristic) being systematic decisions, see figure 2.

Type of Classification	Relationality	Examples
1. Cataloguing	Identification only	Type of decision "investment"
2.Grouping A) Dichotomous B) Multiple	Classified into one of two categories	Programmed and non programmed decisions
	Categorised into n categories (no inter set relationships)	Classification of accounts- current assets fixed assets equities etc....
3. Dimensioning	Selected attributes or dimensions, may or may not be ordered by relationship	Cross classification of functional and investment decisions
4. Ordering A) Ordinal B) Interval C) Ratio	Establishes a rank	Employee ranking by seniority
	Determines differences and assesses complexity	Decision X is 1.5 times as complex as decision Y
	Items are positioned in relation to two or more scales	Classifying personality traits by multi-dimensional traits
5. Systemizing A) Decomposition B) Network C) Static Reciprocity D) Dynamic	Breakdown a decision into constituent parts which can be reconstituted	A) Unit costing B) A decision tree
	Elements of a classification are connected by a causal network of relationships	A) classification by logical analysis B) Analysis of decisions by flowcharts
	There is a mapping of the cause and effect relationship as a static analysis	A) Classification through input output B) Cost benefit relationships
	Mapping of cause and effect relationships is dynamic there is learning through iteration	A) Importance of decision changes B) Decision analysis processes e.g. Monte Carlo method

Figure 2 Classification of business decisions.

The first level of systemizing decomposition, is recognisable from the WBS method of estimation. Additional levels of systemization are available from our understanding of causal networks (CERs in estimation) and these can be mapped through cause and effect analysis. There are therefore two levels of mapping required to develop a systematic estimation process; the mapping of decisions using a decision tree and the mapping of the underlying cause and effect relationships that give context to those decision points. The mapping concept is visualised in figure 3. Cause and effect analysis is normally mapped using the fishbone diagram (Ishikawa, K. 1985)

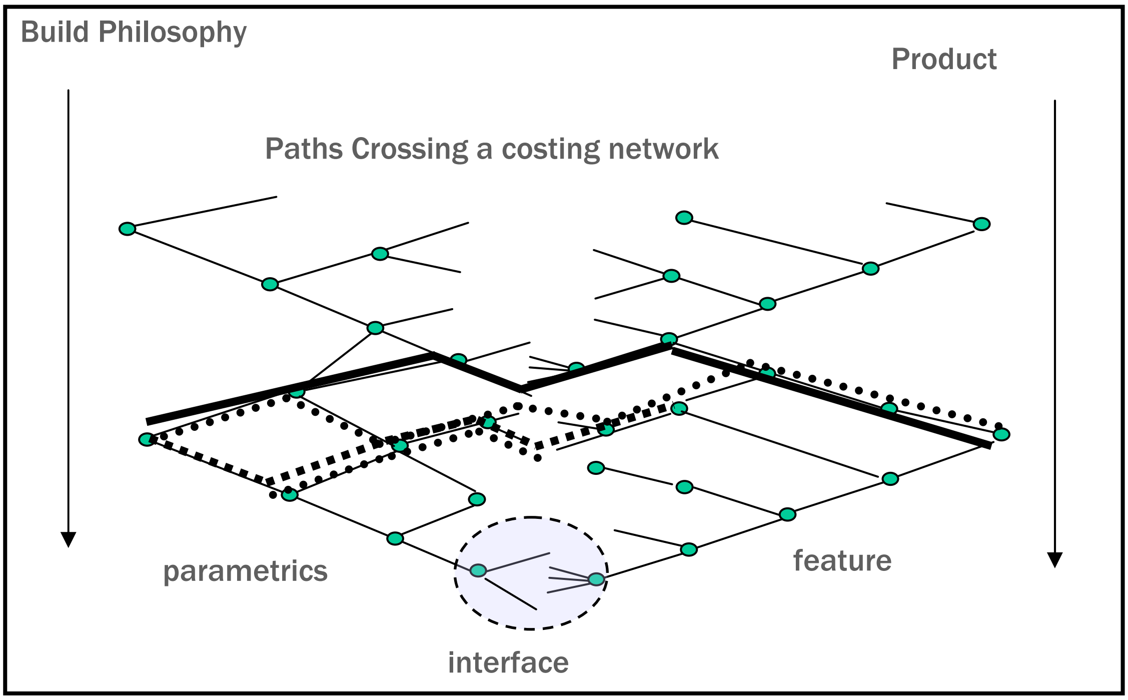

Figure 3 Estimation decisions mapped as a network covering the maturing product design and its required manufacturing capacity characteristics.

8 Conclusions.

The modelling of manufacturing NRC is becoming more important although with new technologies and build philosophies also more complex, opportunities to link models of NRC and RC to model the full product lifecycle seem desirable.

State of the art for NRC in both construction and manufacturing of NRC models is less sophisticated than RC modelling for manufacturing. There is an opportunity to develop strategies for the development of NRC models that increases their value by anticipating synergies with existing RC models.

The future of modelling manufacturing costs may have already moved into the realms of a partnership with marketing models to maximise units sold. What remains to be incorporated into models and is an outstanding NRC issue is potentially fluctuating production rates and strategies to optimise investment in such conditions. The proposed modelling strategy aims to use a systematic response to the variables in NRC estimation while retaining links with the established RC modelling methods.

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