MANUFACTURING AND FORM POSTPONEMENT

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ABSTRACT
Postponement is a growing trend in manufacturing. It can lead to superior supply chains. Form postponement (FP) involves the delay of final manufacturing until a customer order is received and is commonly regarded as an approach to mass customisation. Mass customisation is a trend towards the production and distribution of individually customised goods and services for a mass market. It is providing numerous customer chosen variations on every order with little lead-time or cost penalty. This research project aims to address how FP is applied within the manufacturing facility.

KEY WORDS Postponement, Form postponement, Mass customisation, Modularity etc.

I. INTRODUCTION
A supply chain is the system of organizations, people, technology, activities, information and resources involved in moving a product or service from supplier to customer [8]. To meet the challenge of high demand uncertainty caused by product proliferation, several supply chain strategies like component commonality, modularity, postponement and/or delayed differentiation etc. are applied [10]. Postponement strategy plays a very important role in meeting the challenge of high demand uncertainty at finished item level. Form postponement plays a major role in coping with the challenge of high demand uncertainty due to product proliferation. Form postponement (FP) involves the delay of final manufacturing until a customer order is received. Form postponement has been proposed as one of the more effective approaches to mass customisation.

MTS (make-to-stock) approach aims to conduct final manufacturing, and most inventory movement, in anticipation of customer orders - normally to sales forecasts. Thus postponement reduces the risk of improper manufacture or inventory distribution associated with MTS [2]. At the other extreme, MTO (make-to-order) is where the manufacturer takes no action until receipt of a customer order. Postponement compared to MTO improves responsiveness and still enables a high level of customisation which leads to Mass customisation [11]. The application of postponement has been observed as a growing trend in manufacturing and distribution. This paper focuses on Why and How Form postponement is applied in industries to cope with the challenge of high demand uncertainty at finished product level. The method selected is Case study approach [3].

II. LITERATURE REVIEW
A. Form postponement

FP is the delay, until customer orders are received, of the final part of the transformation processes, through which the number of different product items proliferates and for which only a short time period is available [1]. The postponed transformation processes may be manufacturing processes, assembly processes, configuration processes, packaging, or labelling processes.

This definition acknowledges that the postponed process may take place not only at a warehouse but at a factory or even at the retailers, and these locations may be near to or remote from the customers. The diversity suggested by this definition is evident in practice.

For example, Benetton dyed their jumpers in their main factory in Italy and Xerox configured their office digital products to order at their Gloucester plant. Some paint retailers stock the generic paint and a variety of pigments mixing them to specific customer orders. When variety is added in the factory it is likely to involve the postponement of substantially more complex processes and the operational implications are more significant and difficult to manage.

The term ‘unicentric FP’ is given to applications where the postponed process is performed in the same location as the generic processes (normally the factory) – adding variety at the point of manufacture rather than in the distribution chain [5]. Alternatively the term ‘distribution FP’ is given where the postponed process takes place in the distribution chain. This research is confined to unicentric FP [14].

The dimensions are the degree of postponement-speculation in logistics and manufacturing. Logistics can range from a speculative strategy where inventories are speculatively distributed, and therefore decentralised, to a postponement strategy where distribution is postponed, and therefore inventories are centralised [11]. Manufacturing can
range from a speculative strategy characterised by MTS, to a FP strategy.

B. Case study research

A case study research design has been used to address the complexities of applying FP.

Case study research may be defined as “an empirical inquiry that investigates a contemporary phenomenon within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident” [13].

The main justification for case study research is the relevance versus validity argument. OM research has failed to be integrative, is less sophisticated in its research methodologies than the other functional fields of business, and is, by and large, not very useful to operations managers and practitioners[6]. On the one hand variable oriented research is based on the application of multivariate statistical techniques, delivers broad generalisations and seeks average influence across a variety. But conclusions tend to be vague and abstract and have an ‘unreal quality’. In contrast case-orientated research is based on the application of multiple methods which seek to account for all deviating cases creating a rich dialogue between theory and evidence.

The key strength of the case study approach is that it does not isolate the phenomenon under study from the context in which it exists. On the contrary it allows the phenomenon to be studied in relation to its context [6]. This is a consideration that is largely ignored by more variable oriented approaches, such as surveys or modelling, and results in many of the identified weaknesses of this approach. Case-orientated research is based on the application of multiple methods which seek to account for all deviating cases creating a rich dialogue between theory and evidence [7]. This is particularly significant for the proposed research concerning the application of FP because this body of research is still small.

III. RESEARCH DESIGN

A. Research Questions and Hypotheses

The aim of this research is to understand the reasons for applying Form Postponement in manufacturing and more importantly how it is applied compared to the more established MTO (Made To Order) and MTS (Made to Stock) approaches.

The research question is:

Why and how is form postponement applied in manufacturing?

The theoretical framework developed addresses the research question by illustrating how FP is applied in terms of a wide range of variables relative to MTS and MTO. The hypotheses were extracted from the theoretical framework.

Each hypothesis compares FP with either MTO or MTS with respect to each of the variables as presented below:

1. What is the demand profile of products selected for manufacture under FP?

H1: Products are selected for manufacture under FP rather than MTS when they exhibit high demand mix, high demand variability, and low volume demand at finished product level.

H2: Products are selected for manufacture under FP rather than MTO/ETO when they exhibit high volume demand at generic product level.

2. What is the impact on customer service of FP?

H3: FP considered as an alternative to MTS increases ex-stock availability.

H4: FP considered as an alternative to MTO/ETO reduces order lead-times and increases delivery reliability but introduces demand amplification

3. What are the product design implications of applying FP?

H5: Product families subject to FP will have a higher level of standardisation and modularity than product families subject to MTO/ETO

4. What are the manufacturing planning and scheduling implications of applying FP?

H6: Capability of the postponed transformation process to respond to high demand variability requires excess capacity and high throughput efficiency

IV. RESEARCH METHODOLOGY

Case study method was used for this research. Two distinct approaches were available for the case study design. The first was to study manufacturing facilities that applied FP, ‘postponers’ and compare them with ‘non-postponers’[12]. The selected second option was to study manufacturing facilities where FP was applied and compare units of analysis (UoA) based around product groups subject to different inventory management policies – FP, MTO and MTS [4].

The case study research design based on ‘meta-level’ analytical framework enables change to be studied in different environments without theory limitations in comparative case study research [9].

A case study was carried out at a cable factory PCC in South India. The FP approach had been applied to a selection of PCC’s products. What was not initially clear was that the present day application could no longer be defined as FP. This led to a retrospective rather than a real-time study as initially planned. The objectives of the case study remained to trial the research design
(particularly the use of units of analysis), to firm up the hypotheses and to develop measures or indicators for the concepts featuring in the hypotheses.

![Figure 1 Diagram illustrating the structure of the case study](image)

This case study is structured according to the diagram in Figure 1[9]. The contextual features relating to FP are presented in the first part which includes descriptions of the products subject to FP, the manufacturing processes used to make them and the reasons for applying FP. The key aspects of how the research design was applied in this specific study are described in the second part.

The ‘change content’ when FP was applied in a previously MTO and MTS environment is described in the third section. This includes selection of products and customers for FP, changes to inventory management and manufacturing planning. In the fourth section the ‘outcome variables’, which are the quantitative concepts tested in the hypotheses, are presented. The case analysis is presented in the fifth section which includes an evaluation of the major flaws in the FP application and testing of the hypotheses against the findings. The paper closes with conclusions from the study.

V. CONTEXT

PCC designed, manufactured and supplied flexible cables for transmission of information and energy. PCC had a turnover of around 80 crores and employed 125 people.

PCC’s largest customer was Super Power (SP), a supplier of power leads within an hour’s drive of PCC. SP accounted for 22% of sales in 2009 - 35% if sales to SP’s overseas sites in Middle East and Mexico were included. Clearly PCC was heavily dependent on this business and it was to this supply that they initially applied FP in November 2007. At this time the dependence was mutual as the recent cable industry restructure had reduced SP’s cable suppliers to PCC and one other. Further, PCC was SP’s preferred supplier and in 2007 accounted for 85% of SP’s cable supply. SP’s dependence on PCC was compounded by the fact that SP’s manufacturing was limited to cable cutting and adding plugs. Consequently cable supply was a very high proportion of incoming materials.

A. PRODUCT DESIGN

The cable group studied was described as a ‘3183Y1.00’ cable which was circular shaped with 3 cores. Each core was made up of a copper conductor (cross sectional area 1 sq.mm) which was insulated with PVC to a thickness suitable for ordinary voltage. The three cores were twisted together to make a ‘laid-up’ cable and then extrusion coated with a PVC sheath. Finally the cable was packed, and loaded onto pallets.

Variety in the finished cable was generated from variations in the PVC sheathing compound, winding reel and other packaging materials. The application of FP involved making the standardised laid-up cable to stock and postponing the extrusion of the sheath coating, until receipt of a customer order.

B. MANUFACTURING PROCESSES

The process of cable making could be described as ‘a semi-continuous process’ in that length is processed. Cable length could be an additional variable at each stage of the manufacturing process. At PCC cable length was standardised at each process. However cable length remained a variable at the finished product stage where the customer specified a certain reel length.

The flow process chart in Table 1 shows the processes required to make the cables studied. Copper rod was drawn into multi-end wire which was subsequently bunched (twisted together) to form the conductor. The conductor was extruded with a layer of PVC to make the cores – each of a different colour. Then the cores were laid up (twisted together) to give the laid up cable - the generic stock for the FP approach. Finally the cable was extruded with a final layer of PVC called the sheath. Cable that was ‘direct wound’ (DW) was wound directly onto a despatch reel from the sheath extruder thereby eliminating the rewinding process. This applied to all the cables in the FP UoA and all but eight cables in the MTO and MTS UoAs.
Table 1: A flow process chart for cable manufacturing

<table>
<thead>
<tr>
<th>Process Description</th>
<th>Symbols</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wire drawing</td>
<td>□</td>
</tr>
<tr>
<td>Stow wire by wire drawing machines</td>
<td>□ □</td>
</tr>
<tr>
<td>Move wire to bunching machines</td>
<td>□</td>
</tr>
<tr>
<td>Bunch wire</td>
<td>□</td>
</tr>
<tr>
<td>Move bunch to wire drawing stores</td>
<td>□</td>
</tr>
<tr>
<td>Store bunch in wire stores</td>
<td>□</td>
</tr>
<tr>
<td>Move bunch to core extruders</td>
<td>□</td>
</tr>
<tr>
<td>Core insulation extrusion</td>
<td>□</td>
</tr>
<tr>
<td>Move cores to lay-up machines</td>
<td>□</td>
</tr>
<tr>
<td>Store cores by lay-up machines</td>
<td>□</td>
</tr>
<tr>
<td>Lay-up brown, blue and green/yellow cores</td>
<td>□</td>
</tr>
<tr>
<td>Move laid up cable to sheathing machines</td>
<td>□</td>
</tr>
<tr>
<td>Store laid up cable near sheathing machines</td>
<td>□</td>
</tr>
<tr>
<td>Sheath extrusion</td>
<td>□</td>
</tr>
<tr>
<td>Electrical and physical testing of all cables</td>
<td>□</td>
</tr>
<tr>
<td>Move cable to winding machines</td>
<td>□</td>
</tr>
<tr>
<td>Rewind onto dispatch reels</td>
<td>□</td>
</tr>
<tr>
<td>Move reels of cable to finished cable warehouse</td>
<td>□</td>
</tr>
<tr>
<td>Store reels of cable in warehouse</td>
<td>□</td>
</tr>
<tr>
<td>Dispatch reels of cable to customer</td>
<td>□</td>
</tr>
</tbody>
</table>

C. Reasons for Applying Form Postponement

Interviews were conducted with the Supply Chain Manager, the Works Manager, the Commercial Director, the Business Manager and finally the main contact at the customers, SP. Each informant was asked:

Why was FP applied - what were the drivers?

The reason for applying FP according to both PCC and SP was to increase responsiveness so that the PCC cable supply more closely matched SP’s demand for cable. SP on the one hand wanted to avoid the ‘feast and famine’ supply associated with MTO. PCC on the other hand wanted to fight off competition for the SP business and at the same time reduce the very high levels of finished stock they held.

VI. APPLYING THE RESEARCH DESIGN

A. Identification of Units of Analysis

In PCC there were two main manufacturing areas:

- one which had the capability to produce the full range of cables and manufactured the low volume, specialised cables, and
- the ‘Volume Flex’ area, which had limited capability but manufactured the high volume products, including almost all the cables supplied to SP.

Both these areas were supplied by copper conductors from the ‘Conductor Forming’ area and cable produced in them was sometimes rewound onto dispatch reels in the ‘Winding’ area.

All the products subjected to FP were manufactured exclusively in the Volume Flex area. Here cables were made according to a number of inventory management policies.

As a result the study was confined to the Volume Flex area. The Conductor Forming area was scoped out of the study since the copper wire was drawn speculatively (to a common stock for all cables) regardless of inventory management policy. However, the Winding area was scoped into the study, because rewinding the cables onto smaller reels was a manufacturing process - commonly performed to customer order – but sometimes speculatively. The period of study was from 1st January to 31st May 2008.

The MTS approach was split between make-to-dedicated stock and make-to-speculative stock. However, during the study period the make-to-speculative-stock approach only accounted for about 4% of the volume manufactured in the Volume Flex area - an insufficient volume for a UoA. Overall eight cable groups accounted for 90% of sales. The FP approach was applied to five different cable groups and the two groups produced (under FP) in the highest volumes were 3183Y1.00 and 3182Y1.00. The 3183Y1.00 cable group was selected for the UoA, because it accounted for the greatest proportion of cable sales overall - 20% of cables manufactured in the Volume Flex area were 3183Y1.00.

B. Data Collection

This was a retrospective study where the majority of the data collected applied to the period between 1st January and 31st May 2008. Interview data required support from documentary evidence, and fortunately all the interviewees were not only still employed at the factory but in the same roles as for the study period. This meant that all the informants had first-hand experience and knowledge of the time period in question. Overall the reliability and completeness of the data were only marginally affected by the retrospective nature of the study.

VII. CHANGE CONTENT

A. Product and Customer Selection for Form Postponement

In common with “the reasons for applying FP” how products and customers were selected for FP was the subject of interviews with five different informants. The two questions asked of all informants, and their collective answers, are presented below:

Was the FP approach limited to certain customer, and if so why?
PCC limited the application of FP to cables supplied to SP because of problems adapting the existing production scheduling system to support FP. The first problem was the control of the generic cable stock levels. This was critical – a shortage in these stocks would almost certainly have resulted in a late delivery.

The second problem concerned the limitation of the scheduling system to weekly time buckets rather than daily, as required for FP.

Was the FP approach limited to certain product specifications, and if so why?

The finished cables subject to FP were largely selected by SP on the basis of the volume they consumed. Those used at the highest rates - categorised as ‘runners’ – were selected.

When PCC first approached SP about FP, PCC were supplying about 50 different finished cables to SP. The SP representative split these cables into three categories ‘runners’, ‘repeaters’ and ‘strangers’ according to the volume (average weekly usage) and frequency of usage at SP (daily, weekly etc). Runners were the high volume cables that were used by SP daily. Repeaters were used weekly. Strangers were only occasionally used and were generally cables required for a specific SP customer.

Four out of five of the cable groups selected for FP were in the top six selling cables, which accounted for 85% by volume of sales. In general the cables classed as ‘runners’ were selected for manufacture under the FP approach. Cables were categorised by SP according to usage at finished cable level not at cable group (or the generic) level. For a given generic cable, some finished cable variants were therefore subjected to FP whilst others, with only a different sheath colour, were supplied under the MTO approach.

B. Inventory management

Evidence for inventory management was gathered from interviews with the Commercial Director, Sales Manager, Supply Chain Manager and the two Customer Service Assistants dealing with the respective customers. Cables were manufactured using the FP approach for one customer only – Very Power (SP). The cable orders from SP were processed according to a weekly cycle. Every Tuesday SP supplied an order schedule for cables subject to FP. The order schedule specified the quantity of each finished cable to be available each day. Prior to the application of FP, cables were MTO for SP. Unlike other MTO customers - who accepted delivery upon completion - SP was given ‘special treatment’ and allowed to call-off finished cable. SP only called off cable when required, since they were invoiced upon despatch. Therefore, PCC effectively held SP cable stocks which SP controlled by placing orders and call-offs.

C. Manufacturing Planning and Scheduling

It covers the process from the orders being present on the Master Production Schedule (MPS) to factory orders being scheduled and monitored through the operations. Evidence was gathered via interviews with the Scheduling Manager, the Supply Chain Manager and the Works Manager.

Orders subject to FP were always received and logged onto the SOB on Tuesday, whereas orders for MTO cables or MTS cables were logged onto the SOB any day of the week.

For FP orders the Preplan, the first stage was run over Wednesday night such that manufacturing jobs were available on PMCS, for allocation to the sheath extruders, on Friday morning. This allowed cable due to be available 6.00am Monday morning to be processed either Friday or on overtime over the weekend.

With the exception of bringing the Preplan forward to Tuesday night, this procedure reduced the order processing and planning lead-time to a minimum of 3 days. At first glance this appeared a significant improvement on the 4 to 8 day processing time for MTO cables; however this was not the case and led to the deterioration of the FP application.

Table 2: Main features of manufacturing planning compared for MTO and FP.

<table>
<thead>
<tr>
<th>Features</th>
<th>Stock Replenishment Orders</th>
<th>MTO</th>
<th>FP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manufacturing Orders</td>
<td>Processed by MRP system driven by one week period MPS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Customer Orders entered onto SOB</td>
<td>n/a</td>
<td>Anytime during the week</td>
<td>Tuesday morning</td>
</tr>
<tr>
<td>Preplan ran once each week</td>
<td>Friday night</td>
<td>Wednesday night</td>
<td></td>
</tr>
<tr>
<td>Manufacturing orders released onto PMCS</td>
<td>Tuesday morning</td>
<td></td>
<td>Friday morning</td>
</tr>
<tr>
<td>Duration of manufacturing planning process</td>
<td>84 hours over 4 nights (due to weekend)</td>
<td>36 hours over 2 nights</td>
<td></td>
</tr>
<tr>
<td>Order processing and manufacturing planning lead-time</td>
<td>n/a</td>
<td>4 to 5 days (depending on day of week order was received)</td>
<td>3 days (excludes possible waiting time of 5 days)</td>
</tr>
</tbody>
</table>

VIII. OUTCOME VARIABLES

A. Demand Profile

Evidence for the three demand measures was gathered from archived customer order and call off documents. The ex-works due date was taken as the delivery due date for all orders with the provision that for export there was a transit time. All factory orders for the UoA were identified on PMCS. All archived customer order documents were available for the FP UoA however for the MTO UoA
21 out of the total of 79 customer order documents were missing. The factory order due dates into despatch were known from PMCS and were generally the Saturday before the ex-works due week. Therefore it was possible to estimate the ex-works due date for the missing orders.

About half the archived customer call-off documents, for the MTS UoA, were missing. However, the actual ex-works dates for these call-offs were available on PMCS. Further, comparison with existing call-off records revealed that these dates were sufficiently close to the call-off dates to provide accurate average demand measures over the five-month study period.

The variety of finished cables was driven by the sheathing compound (as well as packaging materials), which was available in 100 different colours and around 10 PVC types.

Contrary to predictions, both demand mix and demand variability were lower - and demand volume was higher - for cables made under FP than those made under MTS. This was due to restriction of FP to one customer and its application to cables which exhibited a volume demand (end item level) high enough to justify a consignment stock of the sheathing polymer. As expected, products selected for manufacture under FP rather than MTO exhibited an average demand volume, at generic level, almost twice that demonstrated by the MTO products.

### B. Demand Amplification

Demand data presented in the previous section was used to measure the demand imposed on the manufacturing system for the FP and the MTO UoA. Jobs were sequenced and allocated to machines on a daily basis and ‘booked off’ upon completion (by the Operator) on PMCS. Therefore the operation booking off dates were within a day or two of the scheduled output dates and accurately represented the scheduled sequence of jobs at each process.

### C. Customer Service

Three measures were used to monitor customer service - order lead-time, delivery performance and ex-stock availability.

Average promised order lead-time was the same as the standard quoted lead-time for orders subject to FP - 8 days. However average actual order lead-time was double this at 16 days. This was due to SP not calling off cables upon completion. If time in FGS, resulting from the delayed call offs, was excluded the actual order lead-time dropped back to 8 days.

The MTO service offered to SP was far more responsive than that offered to other customers. Both the promised and achieved order lead-times (excluding time in FGS) for the SP orders was less than half that for other customers. The FP approach improved the responsiveness of the service further. The actual order lead-time (excluding time in FGS) achieved by FP was one third of the average lead-time achieved by MTO overall (24 days) and just under half of the lead-time achieved by MTO specifically for SP (18 days).

<table>
<thead>
<tr>
<th>Measures</th>
<th>FP</th>
<th>MTO</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of orders assessed</td>
<td>82</td>
<td>30</td>
</tr>
<tr>
<td>Standard quoted lead-time</td>
<td>8 to 10 days</td>
<td>21 days</td>
</tr>
<tr>
<td>Average promised order lead-time</td>
<td>8 days</td>
<td>49 days</td>
</tr>
<tr>
<td>Average actual order lead-time</td>
<td>10 days</td>
<td>53 days</td>
</tr>
<tr>
<td>Average order lead-time excl. delay in FGS</td>
<td>8 days</td>
<td>42 days</td>
</tr>
<tr>
<td>Control of deliveries</td>
<td>1/2 called-off daily</td>
<td>Delivered upon completion</td>
</tr>
</tbody>
</table>

Actual order lead-time (excluding time in FGS) achieved by FP was just under half of the order lead-time achieved by MTO for SP. However, delivery reliability was lower for SP orders produced under FP than those manufactured under the MTO approach - only 51% of FP orders compared to 76% of MTO orders were available OTIF.

### D. Product Modularity

The cables manufactured by PCC were very simple but highly modular. The cores were considered modules each with a discrete function - to transmit an electric current. The sheath also was a module with one function - to mechanically protect the cores. The core could be split into two modules: the copper conductor (or bunch) that transmitted a specific level of electric current; and the PVC coating which insulated the conductor to a specified rating. Different components, in this case sheathing polymers, were paired with the same basic product, a laid-up cable, to produce variety in the finished product.

### E. Product Standardisation

The level of product standardisation was indicated by the proportion of components common to all variants in the UoA and the degree of commonality index. The full indented BOMs sourced from the MRP BOM module were analysed for the 3183Y1.00 cables within each of the UoA. These BOMs had five levels. Levels 4 and 5 were excluded from the analysis because they were only concerned with the
manufacture of one conductor specification (common to all cores in all the cables under study). The number of components in each cable was very similar – 17 or 18. The proportion of common components was highest for the FP UoA. In fact only two components varied – the polymer and pigment to make the sheath. The MTO UoA had the lowest proportion of common components because three cable specifications used non-standard cores (extruded with a special PVC compound). The cables in the FP UoA exhibited the highest degree of standardisation both in terms of the proportion of common components and the degree of commonality index.

F. Excess Capacity
Excess capacity was indicated by ‘planned out’ time, Overall Equipment Effectiveness (OEE) and capacity provision. Planned downtime at each work centre was recorded over the study period (though it was excluded from the OEE measure) and it included ‘planned out’ time - the time periods when demand was not expected to require the work centre capacity. In the words of the Works Manager: ‘planned out time was spare capacity’, or excess capacity. OEE was used to measure capacity utilisation at PCC. The OEE data was gathered for the first 12 weeks of 2008 (4th January to 28th March 2008). The ‘quality rate’ was always 100% because quality defects were not detectable at this stage in production. The ‘net performance’ tended to be high, in the late 90’s in percentage terms, while ‘availability’ accounted for the bulk of the losses generally measuring between 70% and 80%.

G. Throughput Efficiency
The throughput efficiency was measured by tracing jobs back through the value adding processes using the Short Interval Control (SIC) sheets. The time period in finished goods stock was not included in the elapsed time measure because, for SP orders, it was controlled by SP not PCC. The value added time was the time period recorded on the SIC sheets when the job was being processed at the value adding operations. The total number of jobs measured was limited to twelve. For the purposes of comparison between the FP and MTO UoA the orders sampled from the MTO UoA were restricted to SP orders. Four jobs were sampled from each UoA, however it was not possible to trace any of the MTS and two of the MTO jobs through the laying-up process. The time in core stock is relatively unaffected whilst the time in laid up cable stock is considerably extended for FP orders. With the exception of the FP order which achieved a throughput efficiency of 40%, the extended time in laid up cable stock has approximately halved the throughput efficiency of FP orders compared to MTO orders.

IX. CASE ANALYSIS
A. Why the FP application deteriorated
Originally SP agreed to call-off orders subject to FP, in full, upon completion - leaving no finished stock at PCC. Clearly SP’s requirements changed within the order lead-time. The SP representative gave two reasons why SP deviated from plan. Firstly Production would invariably start producing jobs early. Secondly, SP’s customers were regularly offered 7 day order lead-times rather than the standard quoted lead-time of 14 days due to the absence of strategic finished stocks. The FP approach allowed the order lead-time to be more than halved compared to MTO. The existence of high levels of finished goods stock meant it no longer made sense to maintain a generic cable stock in order to manufacture on a short order lead-time. The extended order lead-time meant that even the manufacture of the generic cable was effectively customer-order-driven. This changed the FP application to a slightly more responsive MTO application.

B. Hypotheses Testing
The findings from the PCC case study were not as predicted by the six hypotheses – one hypothesis was challenged (H1) and three further hypotheses were challenged in part (H4, H5 and H6). One hypothesis remained untested (H3) and another hypothesis was untested in part (H6).

X. CONCLUSIONS
The FP application was flawed to the extent that after nine months it could no longer be defined as FP. The finished cable stocks controlled by the customer persisted. The planning system was too inflexible to support the FP application without the support of finished cable buffer stocks. The planning lead-time for FP orders had not been reduced compared to that for orders subject to MTO. Instead PCC’s planning system was synchronised with their customer’s system, but this did not take into account the customer’s high level of deviation from their manufacturing plan. Anomalies in the findings were the result of the flaws in the FP application which challenged three hypotheses. The challenge to the demand profile hypothesis (H1) was the combined result of two factors. Firstly the FP application (unlike MTS) was restricted to one customer. Secondly in general only high volume end item cables were selected for FP to
justify a consignment stock of the sheathing polymer. The challenges to the delivery reliability and excess capacity hypotheses (H4 and H6) were attributable to the existence of finished cable stocks due to the mismatch between supply and demand. No research design is without its limitations and this research is no exception. Upon reflection of the entire research process three aspects, Case selection, Data availability and Generalisability of the findings stand out as limiting the findings.

Further case studies are to be conducted to understand the success of FP and to find out why and how is Form postponement applied in manufacturing.

REFERENCES