Aggregate planning for seasonal demand: reconciling theory with practice

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Abstract

Purpose – The paper reports on the ramifications for production planning when monthly sales exhibit predictable seasonal highs and lows. The literature first acknowledged and dealt with the (aggregate planning) problem 50 years ago. Nevertheless, there is neither evidence that industry has adopted any of the mathematical techniques that were subsequently developed, nor a convincing explanation as to why not. Hence this research sets out to discover the methods manufacturers use to cope with seasonal demand, and how germane the published algorithms really are.

Design/methodology/approach – Forty-two case studies were compiled by interviewing senior managers and then conducting plant tours. No prior assumptions were made and the list of questions covered the gamut of production planning.

Findings – The main finding is that manufacturers select a straightforward production strategy, right from the outset, so the fundamental cost-balancing format is not relevant. The majority pick a "chase" strategy, since most organizations subscribe to a "just in time" ethos. Whenever a different strategy is preferred the rationale springs from skilled labour considerations or binding facilities constraints. The chosen strategy serves as a road map for resources acquisitions, and the master production schedule is constructed directly. So, the complex issue of how to disaggregate an optimal aggregate plan never even arises. Managers do not seek perfect solutions, but strive to eliminate, or contain, the most significant marginal costs. The nature of the business determines the most appropriate tactics to employ.

Originality/value – These findings break the mould as far as orthodox aggregate planning is concerned and show why theory is at odds with practice, whilst reaffirming the importance of concepts such as "flexibility", "integration", and "just-in-time production".

Keywords Corporate strategy, Production planning, Productive capacity

Paper type Research paper

Introduction

Demand for many products conforms to a repetitive annual cycle, due perhaps to the climate, Christmas shopping, or the start of the new school year. Seasonal variations cause special difficulties in scheduling production and ensuring that the right resources will always be on hand. Holt *et al.* (1955) were first to discuss the problem, using data from a paint factory. The fundamental premise was that two pure production strategies exist, namely "level" and "chase". A "level" plan maintains a constant daily (aggregate) production rate, and draws upon stockpiles of finished goods whenever monthly outputs dip below their matching sales marks. Alternatively, a "chase" type plan adjusts the labour inputs in order to track the expected monthly demands. Common tactics for varying capacity are overtime or undertime, hiring or firing to change equipment manning levels or the number of operational shifts, and subcontracting some work out. Normally, a certain combination of "level" and "chase"

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plans (a "mixed" strategy) minimizes the total marginal (labour-inventory) cost summed over a 12 months horizon. To simplify the calculations, sales forecasts, inventories, labour inputs, and production rates are all expressed in suitable aggregate terms. Since it is impossible to manufacture "aggregate products", the (optimum) aggregate plan needs to be disaggregated into an equivalent product-based master production schedule (MPS) with an identical cost structure. Krajewski and Ritzman (2005) suggest that this should be an iterative process, with possible adjustments to the aggregate plan allowed, as the initial attempts may not yield a feasible result.

Aggregate planning has proved popular with researchers demonstrating the prowess of different analytic techniques. These included linear decision rules derived from differential calculus (Holt *et al.*, 1955), and simulation (Jones, 1967; Taubert, 1968), production switching rules (Elmaleh and Eilon, 1974; Mellichamp and Love, 1978), and various branches of mathematical programming (Bowman, 1956; Akinc and Roodman, 1986). Both goal programming (GP) (Deckro and Hebert, 1984; Gilgeous, 1989) and a tabu search algorithm (Baykasoglu, 2001) featured "soft" policy considerations alongside the regular cost minimization objective. Such amendments were deemed necessary because there are virtually no reported industrial applications (Nam and Logendran, 1992).

Hwang and Cha (1995) modified the switching rule, so management could stipulate desirable inventory levels, whilst Silva *et al.* (2000) adapted the linear decision rule to find the optimum fixed number of employees. Another "level workforce" model (Hung, 1999) specifies a flexible labour contract with annualised hours and provides a "chase" solution. In similar vein, Chen and Liao (2003) constructed a mathematical programming model with a multi-criteria objective function and an even workforce. Overtime was the sole means of augmenting capacity, but for a financial penalty backorders were allowed. Each product's outputs were predetermined according to an independent production strategy. The rationale was to simplify the corresponding technique. For example, an linear programming (LP) solution was available for the "mixed" strategy. The other strategies amounted to variations of "level" or "chase" plans. Each prospective strategy's efficacy was tested using a multi-attribute decision-making approach.

Gilgeous (1987) and then DuBois and Oliff (1991), conducted postal surveys to discover why business has ignored researchers' efforts so far. The explanations were based on 55 replies from 500 questionnaire recipients, and 82 from 400, respectively. DuBois and Oliff opined that operations could not obtain accurate enough sales forecasts, or sufficiently reliable cost information, to make the computer algorithms worthwhile. Also, managers lack the necessary mathematical expertise. Drawing an entirely different conclusion, Gilgeous proposed expanding the rudimentary paradigm to cater for the different objectives of business functions like human resources, marketing, and finance.

Thus, despite the previous efforts, the reasons behind the dearth of industrial applications for aggregate planning algorithms remain somewhat of a mystery. There is a more pressing problem though with the underlying theory. How does a cost minimization model, which may actively encourage the stockpiling of finished goods, fit in with the current belief that just-in-time (JIT) production represents the ultimate goal? Also, JIT relies upon shop floor initiatives to continuously improve working methods, rather than just accept mathematical solutions to static (economic batch

quantity) models at their face value. Such questions have provided the motivation for the research program outlined later in this paper.

Integrated production planning and control

Any medium term aggregate plan is but a step along the way to a pragmatic, cost effective, shift-based program that satisfies market needs. The MPS is pivotal in the overall process, but no guidelines are available to derive it from the preceding aggregate plan. Hierarchical production planning (HPP) methodology maintains a rigid connection between the two plans (Bitran *et al.*, 1982; Hennet, 1999), but its algorithms are restricted to single or two-stage manufacturing systems. For instance, Chung and Krajewski (1987) employ a 0-1 integer-programming model that incorporates the batch changeover costs associated with product families. Families comprise products that utilize common machine set-ups. A second LP model breaks the ensuing (semi) aggregate schedule down into an MPS, spreading the specified aggregate resources evenly over corresponding four-week periods. After imposing a "level workforce" policy, Venkataraman and Smith (1996) obtained an aggregate LP solution for a paint factory making 79 individual products. An integer GP technique decomposed this coarse schedule into 17 constituent families obeying minimum batch size rules. Ozdamar *et al.* (1996) merely state the aggregate plan. Their algorithm is designed to minimize family changeover costs.

HPP boasts two factory applications. A fibreglass plant's management determined the permissible inventory range and nominated several feasible output/capacity configurations (Burch *et al.*, 1987). Under an extension to the production-switching rule (unsuitable for significant seasonal bias), the impending month's sales forecast may trigger the allocation of more (or less) labour to operations. Daily schedules are computed by assigning families to semi-dedicated looms and finding efficient combinations for simultaneous batch production, or directing them to specific production lines and determining the best batch sequences. A food factory's lines are dedicated to families requiring similar, expensive set-ups (Allen and Schuster, 1994). Changeovers between family members waste little time. The plant experiences demand spikes that exceed capacity constraints. Nevertheless, planning only covers six months, with no indication of seasonal influences. During the immediate four weeks, family changeovers, family inventory charges, and the overtime budget come under scrutiny. Across the remainder of the schedule the technique just juggles monthly inventory charges against the overtime bill. The method's second phase disaggregates the first four weeks, minimizing the combined set-up and holding charges for individual products.

An apparel manufacturer harnesses management science methods (not HPP) to integrate the aggregate planning and MPS stages and thereby tackle the problem of excessive inventories (Edwards *et al.*, 1985). There are 10,000 plus stock keeping units (SKUs) for jeans alone. Seven distinct models were developed. However, management insisted on an even workforce and a simulation model produces a "level" plan for each product line (for example, men's corduroy jeans). When line data are disaggregated back into lot format (for example, men's corduroy jeans, straight leg, blue) staple lots are allocated proportionally more smoothing stocks than fashion-oriented garments. Next, target inventories are split into the different sizes, before a weekly manufacturing schedule is compiled with economic batch quantities.

Research scope and methodology

The main aim was to discover why practitioners fail to utilize aggregate planning algorithms. Moreover, it would be prudent to establish what is done instead and why firms actually plan that way. For nearly 50 years a void has existed between theory and practice, which calls for a fresh approach. Consequently, the investigation commenced without preconceptions, and broadened the scope of previous work by exploring how the different tiers of production planning dovetail together, and the extent to which flexibility is conserved as one plan gives way to the next.

Bearing these points in mind, the case study methodology is best suited to understanding complex decision-making processes and capturing relevant information (Eisenhardt, 1989; Baines and Kay, 2003). Collecting such data are time consuming. Notwithstanding, the research community is prone to query pronouncements based on a few examples, fearing the sample may be biased. Eventually, the project encompassed 42 manufacturers, which is large by case study standards. Thus the sample is comparable to both surveys cited and much richer in information content. The plants are located in rural and metropolitan areas of South-eastern Australia, and sales display a marked seasonal effect. Participants were deliberately drawn from a wide range of industries, with different production processes, whilst aiming for a mix of winter and summer sales peaks. In addition, the sample traversed the spectrum from small family businesses to subsidiaries of large foreign multinationals. The desired balance was achieved by targeting appropriate firms, found by reading the business sections of newspapers, *Yellow Pages* telephone directories, and the packaging of relevant goods found in the shops.

Each case involved a semi-structured interview with the proprietor, chief executive, or a senior executive (usually the company nominated the production manager), followed by a plant tour to make observations and put further questions to other staff. A checklist was available. Case contents were confined to the production planning arena, and covered the overall strategy for dealing with seasonal demand, the format and goals of (broad) production planning, scheduling resources, construction of the MPS, management issues, shop floor constraints, and volume and mix flexibilities.

Table I provides a quick reference list of the 42 cases and the Appendix gives brief details. To process and analyse so much qualitative information, and present the results in a transparent fashion, is quite a daunting task. So, three cases (marked with an asterisk in Table I) appear in précis form. The idea is to illustrate the nature of the investigations, highlight the diverse circumstances that firms operate under, and demonstrate how sifting through numerous salient facts and searching for common traits has led to certain generic propositions.

Three representative cases

Case 12 – refrigerators

A JIT credo pervades the refrigerator plant since these are large, expensive items. Combinations of 15 sizes, three brands, and three colours spawn a vast number of products. Furthermore, individual models have a short life, aside from one or two "appearance" changes per year, plus frequent modifications for cost, manufacturability, and legal (environmental) reasons. The public buys more units in summer than winter, so a 20 per cent monthly swing occurs. November is the peak month when retailers stock up for Christmas. The facility shuts for two weeks over

Table I. The case studies

Number	Product	Main strategy	Secondary strategy
1	Bulk/bagged cement	Chase	Level output at intermediate stage
2	Petrol and oils	Chase	Exports
3	Industrial paints and varnishes	Chase	
4	Domestic paints and finishes	Chase	JIT production
5	Beer	Chase	
6	Ice cream	Chase	
7	35 mm photographic films	Chase	JIT production
8	Ladies' wear	Chase	Demand management (complementary ranges)
9	Ladies' footwear	Chase	Demand management (complementary ranges)
10	Tumble dryers	Chase	JIT production
11	Lawnmowers, edgers, outdoor vacuum cleaners	Chase	JIT production
12[a]	Refrigerators	Chase	JIT production
13	Electric wall heaters	Chase	JIT production, Engineering subcontract work
14	Nail plate products	Chase	
15	Jewellery	Chase	
16	Greetings and seasonal cards	Chase	Demand management (complementary ranges)
17	Crumpets and scones	Chase	
18	Meat pies, pasties and sausage rolls	Chase	
19	Toys	Chase	Subcontract all production
20	Garden and industrial hoses	Modified chase	
21	Ice cream	Modified chase	
22	Processed foods	Modified chase	
23[a]	Chocolate Easter eggs and Christmas novelties	Modified chase	
24	Pine borders and pavers	Modified chase	Utilize subcontractors for distant markets
25	Surfers' wetsuits	Modified chase	Demand management (complementary ranges)
26	Board shorts	Modified chase	Demand management (complementary ranges), JIT production
27	Pharmaceuticals	Modified chase	Level output over three months horizon
28	Bulk and bagged fertilizers	Modified chase	
29	Bicycle safety helmets	Modified chase	
30	Garden tools and other hardware	Modified chase	
31	Ammunition	Modified chase	

(continued)

Table I.

Number	Product	Main strategy	Secondary strategy
32	Motor vehicle batteries	Level	
33	Colour television sets	Level	
34	Cricket balls	Level	
35	Motor car radiators	Level	
36	Cooling fans and electric strip heaters	Demand management (complementary products)	Modified chase, JIT production
37	Gas barbecues and solid fuel heaters	Demand management (complementary products)	Modified chase
38[a]	Evaporative air conditioners and radiant gas heaters	Demand management (complementary products)	Chase, JIT production
39	Lawn bowls	Demand management (exports)	Level production
40	Marine distress flares and fireworks	Stable (core) workforce	
41	Wood heaters	Stable workforce	
42	School uniforms and club/corporate wear	Modified level	

[a] Three cases appear in précis form

the December-January holiday period, instead of the normal four, followed by two more weeks in July. Two assembly lines run during a day shift and can build any model. Their sole concession to batching is confining low-volume ranges to a single line and the beginning of the month to facilitate parts supply. A conveyor transports matched cabinet and door sets directly to assembly, but small parts are produced and supplied in economic lots. Many purchased items are delivered daily.

The union agreed that 25 per cent of the labour force might be employed on fixed-term contracts of three months duration. If vacancies arise workers bring along their friends. New arrivals need two or three days training before performing simple operations. Once established, recruits are capable of other tasks, providing operational flexibility. The company publishes a rolling 12 monthly sales forecast by brand. Production takes this initial projection and adjusts the workforce each month, rebalancing the lines to "chase" demand. Halfway through the month marketing issues a model-based schedule. This leaves a two weeks lag between the interim plans. So, minor (model) smoothing occurs during the weekly program revisions. Overtime is a last resort, authorized for emergency maintenance, to alleviate bottlenecks, and compensate for rejects.

Case 23 – confectionary

A confectionary manufacturer makes highly seasonal products (Easter eggs, Christmas novelties). The myriad of SKUs springs from different shapes, chocolate brand and type, eight egg sizes, foils, assembly (a big egg packed with different small eggs or sweets), and packaging. Several retail giants are responsible for 75 per cent of the products (usually via custom packaging), leaving small stores to buy the standard lines. The Easter side dominates Christmas novelties 4-1 by volume.

Production entails piping liquid chocolate and filling from the correct holding tanks to a specific mould machine. The three machines are dedicated to hollow eggs, solid eggs, or hollow novelties. Chocolate pieces travel by conveyor to one of eight foil wrap machine groups. Each group handles a limited range of product dimensions. By reconfiguring eight conveyors any mould machine can connect to a specific number of (identical) foil wrap machines within a suitable group. Crews move around too, since not all wrap groups will be active. Moulds and foils can be exchanged quickly, but a switch of chocolate brands consumes a whole shift, and going from dark to milk type forfeits a complete day's production. Brown chocolate followed by white chocolate wastes two to three days flushing out the mould machine. Consequently, the factory tries to schedule a single run per year of the low-volume, white chocolate products. After wrapping, eggs proceed to the packing area.

During February-April all sales are estimated for the coming year. Initial batch runs amount to 70-80 per cent of these preliminary values. Throughout June and July representatives canvass customers about their likely Christmas orders, and in July and August they repeat this activity for Easter products. These new figures establish sales forecasts, which generate second phase production targets. Firm Christmas orders begin to arrive in July, and Easter egg orders are received in December. Throughout January and February, the factory addresses pending Easter shortfalls, along with a spate of rush orders from customers topping up their stocks. There is little chance of product obsolescence, although the company is stuck with any leftover items for almost a year.

The plant runs two shifts all year round, plus occasional weekend overtime for new product trials, rush orders, and to catch up after equipment failures. Items are scheduled as late as possible, but some stockpiling is unavoidable due to insurmountable demand peaks (hence "modified chase"). To begin with there are 120-140 operatives. Eventually, the number doubles, but no labour is added until strictly necessary. In general, training times are short. So, temporary workers are hired on 4-50 week contracts. From October onwards the load in critical sections warrants a third shift. The MPS stretches over 72 weeks. Rigorous capacity planning applies to the front 16 (MRP) buckets, but the rest, comprising four-week intervals, only undergo a "rough" workload check. Most manipulations concern the mould stage (chocolate type plus shape). Even then, the final program must satisfy several further constraints.

Case 38 – air conditioners and gas heaters

An air conditioners manufacturer purchased and relocated a gas heaters business. This demand management strategy brought in counter-seasonal sales. All units are fairly large, complex (the complete bill of materials contains 2,500 items), and expensive. High product variety exists. Total work content is evenly balanced between the product types. Notwithstanding, gas heaters generate a greater proportion of work in press and paint shops, whilst air conditioners place a bigger load on the assembly area. JIT production applies within the factory and for locally sourced parts.

Domestic sales depend on random aspects of the weather and are extremely unpredictable. For heaters, the monthly figure fluctuates 15-20 fold, with up to $\pm$ 40 per cent forecast errors. Portable air conditioners' demand varies by as much as 600 per cent per annum, and one particular year's sales were compressed into a six weeks window. The MPS looks for 2.5 months worth of warehouse stock, although cover drops to one month for "volatile" items. These generous allowances stem from monthly buckets, the large number of models squeezed into the schedule, and forecasts' unreliability. Occasionally, the factory is compelled to react at short notice to export orders, which calls for great mix and volume flexibility.

A day shift runs in assembly, two shifts for components production, and three at bottleneck machines. Management raises capacity by hiring casuals, whose contracts can be terminated with minimal notice. Three hours training suffices for a new team starting up an assembly line. Operatives transfer between different areas in accordance with seasonal requirements, and to promote multi-skilling the workforce rotates jobs every day. Holidays are arranged, as far as possible, to suit sales patterns. Two weeks closure over Christmas and New Year is followed by a one-week break in April or June (depending on orders received), and likewise a further week in September or October. Two of the six (multi-model) assembly lines can switch between a specific gas heater and a compatible air conditioner range. Thus, sufficient process and labour flexibility exists, along with the safety stocks, and the leeway afforded by export orders on long lead times, to more or less "chase" demand.

Senior management produces a rolling, "rough cut", monthly business plan, specified by product range over a one-year horizon. A quarterly review drives MRP. Overseas suppliers of imported components work off the broad-brush plan. Labour planning utilizes the immediate four months. Various marketing departments provide model-based forecasts for this production "window", based on orders received and their own market nous. The final build plan reconciles the new figures with the original

coarse plan via the bountiful inventories of finished goods. A major fortnightly review still occurs, plus minor modifications each intervening week. Overtime is reserved for unplanned situations, when it is impossible to respond fast enough by any other means.

Discussion of findings

Companies always set a predetermined strategy that governs resources acquisition and the formulation of the MPS. Referring to Table I, the "level", "chase", and "mixed" strategies were defined previously, and the "demand management" strategy is recommended in most textbooks, whilst the "level workforce" and "level (core) workforce" strategies are self-explanatory. This leaves the "modified level" and "modified chase" strategies. A "modified" strategy means management pursues the pure policy as far as possible, before encountering a binding constraint. In all cases, the principal interviewee stated quite clearly what strategies their company was using, although these were not necessarily expressed in the terminology preferred here. The only occasions when some judgment was required were when the "demand management" strategy was implemented along side another strategy (8, 9, 16, 25, 26, 36, 37, 38, 39). In fact, the "demand management" strategy only took precedence if the main motivation for introducing counter-seasonal products, or targeting counter-seasonal markets, was to alleviate the seasonal production problem. Significantly, Table I shows 45 per cent of the sample implements a pure "chase" strategy, and an overwhelming 81 per cent favours either a "chase" or "modified chase" strategy. On the other hand, no case adopted the "mixed" strategy, or even contemplated using an orthodox cost-balancing type model.

"Chase" strategy

The "chase" rationale is based on similar logic to JIT production. Thus, the refrigerator case (12) and others from this category (4, 7, 10, 11, 13) equate a JIT environment with the elimination of finished goods (smoothing) stocks. The "chase" strategy is critical when products are valuable (10, 11, 12, 13, 15), bulky, or hard to store (1, 2, 5, 6, 10, 11, 12), and for goods that are perishable (5, 17, 18) or carry an appreciable risk of obsolescence (12, 19). Also, high product variety (say more than 100 end items) rules out accurate sales predictions over long time horizons (3, 4, 6, 7, 8, 9, 12, 14, 15, 16), making stockpiling hazardous, and the degree of uncertainty is compounded when a fashion element exists (8, 9). A "make to order" type schedule (3, 7, 8, 9, 15, 16, 17, 18, 19) prevents any over-production, but this arrangement excludes any recourse to conventional anticipation stocks.

The relationship between the average utilization of fixed equipment and the magnitude of the monthly sales swing is the key factor in determining the feasibility of a "chase" strategy. A modest seasonal profile (say less than a two-fold swing) is a bonus in this respect (1, 2, 3, 4, 5, 7, 12, 14, 16, 18). On the labour side, the most important facilitators are training requirements lasting no more than three weeks (4, 6, 10, 11, 12, 13, 15, 17, 18), easy recruitment (4, 6, 12, 13, 15, 17, 18), flexible employment conditions or short contracts for casuals (4, 6, 8, 10, 11, 12, 15, 17, 18), and some latitude when timetabling plant shutdowns or individual worker's vacations (4, 5, 7, 8, 12, 15, 18).

"Modified chase" strategy

The reason why manufacturers choose this strategy over the "chase" alternative is because limited resources prevent output levels from closely shadowing market

demands. These constraints generally refer to the maximum capacity of the equipment (20, 23, 24, 28, 29, 31), or an inability to ramp up the workforce sufficiently given the lengthy training times involved (25, 26, 29, 30, 31). The training facility may act as a bottleneck too (21, 27), whilst in case 22 certain products must be scheduled whenever their seasonal raw materials (crops) become available.

A "modified chase" strategy calls for some stockpiling, but firms alleviate the risks of holding unwanted goods by making informed tactical decisions. For instance, export orders (31), indent orders (25, 26), and the large orders associated with contract manufacture (27, 31) are all placed well before their required delivery dates. Such jobs are slotted into the MPS sooner than is strictly necessary to smooth out peaks and troughs. The featured case (23) highlights how marketing can assist production to fine-tune the MPS by building up the requisite smoothing stocks in increments. Similarly, Boots uses a three-phase production plan to improve the accuracy of their forecasts for suntan creams (Slack *et al.*, 1998), where sales depend greatly upon the vagaries of the British weather.

"Level" strategy

Manufacturers adopt the "level" strategy because operators take a long time to become proficient at critical tasks (32, 33, 34, 35). Besides, management wants the capital-intensive battery plant (32) to operate at full capacity all year round. All (four) of these plants make stable products with negligible probability of obsolescence. When these two desirable characteristics are combined with low variety (32, 33, 34) forecasts are quite good, and so a modest seasonal factor (32, 33, 35) means small quantities of smoothing stocks suffice. Nevertheless, each business devised specific tactical measures to reduce the attendant risks (which include shortages of some models). For example, marketing discounts prices to achieve the automotive batteries' annual sales target (32). Colour television sets are expensive, so (unplanned) overtime is authorized during the peak period to correct for long range (model) forecasting errors (33). On the other hand, demand for cricket balls (34) is extremely seasonal, but customer credit is extended to procure a high proportion of indent orders. Finally, an enormous variety of radiator cores are supplied to the vehicle aftermarket (35), but smoothing inventories comprise the nine most popular cores. These few units yield 60-70 per cent of sales and guarantee substantial stock turnover. Therefore, with these provisos, the "level" option is a safe and simple strategy.

"Demand management" strategy

The obvious way to stimulate off-season sales is to launch a complementary product range but one should not underestimate the difficulties involved. Two (out of just three) successful examples had to purchase and relocate an independent business (36, 38). Thereafter, most planning revolves around setting the correct product mix each month. The featured case (38) has sufficient labour and process flexibility to "chase" demand. However, cooling fans and electric strip heaters are assembled on separate assembly lines (36), whence permanent employees must switch between these facilities twice per year. Casual workers occupy the vacated fans line for a short period to provide a closer match between supply and demand, but limited amounts of anticipatory stocks cater for the slackest months when there is no corresponding production. Small stockpiles of gas barbecues and solid fuel heaters (37) are necessary for similar reasons. This factory

has greater process flexibility though, swapping the tooling on individual machines to enforce a gradual changeover of the product ranges. Fortunately, the majority of case 36's orders are indents, whilst case 37's retail arm uses discounts and promotions to move any excess stocks.

The dominant global player in a niche market exports to 25 countries to smooth out the bumps in domestic demand (39). Six weeks training rules out volume flexibility. However, the small stockpiles consist of a few popular models exclusive to Australia or the UK (the biggest markets). Several firms in weaker competitive positions tried the same strategy, but with little success.

The remaining strategies

The final three cases rejected a "chase" policy due to skilled labour considerations. At the same time, various physical (41), legal (40), and commercial limitations (42) on stockpiling eliminated the "level" option. So, case 40 hires temporary employees to perform unskilled tasks, releasing some regular staff to augment the output at critical processes, whereas case 41 relies heavily on overtime. Case 42 relieves its small bottleneck section (four weavers) sufficiently through a slight adjustment to their attendance roster. Various tactics reduce the risks of holding smoothing stocks. The pyrotechnics manufacturer stores fireworks because their shelf life is longer than marine flares. Welders constitute the main skilled labour requirement for solid fuel heaters fabrication. By putting welded cabinets into stores the factory can assemble the finished goods (incorporating expensive purchased components) more or less in line with eventual demand. The uniforms maker obtains the scheduling flexibility it needs by encouraging the schools segment to place indent orders.

Labour management

Workforce adjustment decisions are management issues and firms take steps to avoid any financial penalties. Flexible arrangements are invoked, depending upon the nature of the business, the job training required, and the severity of the desired volume leverage. As a rule of thumb, it is worthwhile hiring temporary personnel provided no more than three weeks training applies. Some organizations maintain a register of students, housewives, or retirees seeking temporary employment (4, 6, 7, 8, 14, 23, 24, 26, 27, 29, 36). Short-term employment contracts (full or part time) are rife. A typical contract lasts three months. After that, trade unions insist employees become permanent staff. For perishable products, like crumpets (17) and meat pies (18), the outputs track daily demand. Hence some casual workers report for just a few hours of continuous work. For a small fee, the nail plate manufacturer (14) can hire any number of skilled packers for a single shift at a time, with just a day's notice, from a specialist employment agency. Other firms do likewise (21, 29), or contract out the monthly overloads (9, 15, 24, 41).

In sales troughs, organisations may downsize slightly by not replacing personnel that depart voluntarily or retire (13, 18, 25, 26, 42). Slack periods prove convenient for training, maintenance, and other indirect tasks (5, 7, 24, 28, 42), whilst another ploy involves taking holidays during the off-season instead of at conventional times of the year (5, 7, 8, 12, 15, 21, 23, 25, 26, 29, 30, 35, 36, 38, 40, 42). Sometimes, limited idle time is acceptable, especially in capital-intensive plants or when experienced workers prove too hard to replace (5, 8). Several operations share a site with a bigger (non-seasonal)

department. The combined voluntary turnover enables the whole facility to absorb surplus (seasonal) workers (10, 11, 20).

Half the sample sanctions planned overtime although many businesses find it too expensive. The main justification for regular overtime is so production can chase demand in a flexible manner. Retaining short-term flexibility implies an (planned) overtime limit, beyond which it is prudent to hire more employees. Sales forecasting (and production) is an imperfect science. So, leaving room for unplanned overtime facilitates a rapid response to unforeseen shortfalls. This aspect is especially germane for products with volatile, weather-dependent sales (5, 6, 11, 18, 20, 21, 25, 27, 28, 38).

Outworkers and sheltered workshops represent the cheapest labour. Actually, Krajewski and Ritzman (2005) state subcontracting can cost less than regular production and become a permanent feature. Thus the multinational toy corporation (19) buys in all production, due to full cost considerations. Besides, launching a vastly different product range each Christmas calls for extreme process flexibility. In a "make to order" environment, subcontracting affords a handy buffer to absorb random demand spikes and service rush jobs (9, 15). Furthermore, factories can "chase" demand without investing in duplicate machines (24, 41), whilst guaranteeing high utilization of expensive equipment (Slack *et al.*, 2001). Alternatively, experts in casting, stamping, enamelling, and moulding supply parts to other manufacturers to supplement (low) seasonal production (13, 29). The principal objectives of such subcontracting arrangements are to maximize the revenue stream, and return on assets, not circumvent the aggregate planning problem.

The master production schedule (MPS)

No enterprise in this sample even attempts to construct a genuine aggregate plan, let alone seek an optimum solution. And although planning may commence with targets for family groups, which become model specific at a later stage, there are no complementary steps of aggregation and disaggregation either. In fact, going through the recommended aggregate planning process and ending up with the same labour and inventory costs each month would constitute a Herculean task, compounded by high product variety. This methodological discrepancy is most obvious when there are discrete summer and winter ranges. Then, over the complete year, the concept of an aggregate unit is meaningless, and the critical decisions are the timings of the product changeovers on the production lines (36, 37, 38).

The initial production plan must stretch far enough to accommodate the recruitment and (brief) training of any temporary employees, and the timely acquisition of dependent raw materials. If a "chase" strategy applies there is no need to speculate what sales might be over the rest of the year. Furthermore, those activities with long lead times (for example, purchases of imported parts) can rely on (semi) aggregate figures. Thus, generic product families are adequate for specifying distant portions of the MPS and sales forecasts need not be couched in over-optimistic terms. As the time buckets advance, their contents are defined more precisely. So, when implementation activities are actually triggered, firmer, more accurate, model-based forecasts are available.

The firm's seasonal strategy, plus concomitant labour and stockpiling directives, prepared in advance, facilitates construction of the MPS. Moreover, a lot of the effort that goes into formulating the final version is expended on batch sizing and sequencing

decisions. Pending stock shortages tend to surface at this point. Therefore, the front section is in a state of flux and may undergo various tweaking procedures that reflect the subtleties of loading groups or individual pieces of equipment, the need for full product definitions, and the importance of satisfying customers. In the end, planners focus on using the general guidelines to find an effective schedule that works, not on preserving previously stipulated marginal costs.

Summary and conclusions

Manufacturers respond to seasonal sales by imposing a pre-determined production strategy. Both the jeans example (Edwards *et al.*, 1985) and a soft drinks vignette (Slack *et al.*, 1998) support this stance, which is valid even if computerized lot sizing and sequencing algorithms are subsequently introduced (22). The strategy matches the firm's idiosyncratic operational and commercial environment. Other decisions are made as late as possible, so the MPS is more reliable, robust, and flexible than any would-be alternatives derived from far-reaching aggregate plans. No general rules exist for picking the right strategy. The critical factor is the magnitude of the sales hump in relation to the plant's maximum volume flexibility. About 75 per cent of the sample selected a "chase" or "modified chase" strategy, but no firm plumped for a conventional "mixed" strategy. According to the accepted wisdom, product aggregation is necessary to scale down the potentially complex calculations. In real life, carrying out a straightforward strategy with the aid of a hierarchy of pragmatic tactics makes the overall scheduling problem tractable.

Nowadays, the JIT credo highlights paring warehouse stocks and maintaining a strong cash flow position. Therefore, all things being equal, a "chase" plan is preferred, as the business faces minimum financial exposure. Production should retain sufficient flexibility to react in time whenever demand has been underestimated, because retailers have a critical sales window and generally do not accept backorders. Often, resources constraints render a pure "chase" strategy infeasible. An alternative strategy is selected. Thereafter, supplementary measures (like soliciting indent orders) lessen the risks of stockpiling.

Presently, aggregate planning theory revolves around an eminently plausible yet entirely false doctrine. Consequently, the plethora of techniques to solve different versions of Holt *et al.*'s model is of little use to industry. A new paradigm is proposed, based on observed practice, whereby management begins proceedings by picking a feasible (seasonal) strategy. Furthermore, this mode fits more easily into a coherent picture of the complete production planning process. The textbooks should take some notice and abandon the pretence that manufacturers pursue the "mixed" strategy in order to minimize the combined (marginal) labour and inventory costs. Instead, the importance of adopting the right overarching seasonal strategy and the link between the "chase" strategy and JIT production needs to be emphasized.

At the same time, the recommended process of aggregating the sales forecasts for individual models, finding a good, year long aggregate solution, and then dis-aggregating this plan (faithfully, to retain its optimum character) back into a useful model-based MPS has also been discredited. The correct procedure is to construct the MPS directly, according to the chosen strategy, using real products for the immediate time buckets and (perhaps) family groups for any periods that appear further out. As the timeline advances, and predictions of eventual demands become

firmer, the necessary adjustments are made and an appropriate model mix is allocated to the (gradually) metamorphosing product groups. In this way, the flexible integration of the successive plans is easily achieved.

There are implications for researchers too. Further refinements of existing aggregate planning models coupled with new mathematical techniques to obtain solutions are just a wasted effort. On the other hand, there may be opportunities to tackle certain batch sizing and sequencing problems that arise from significant penalties attached to (family) machine set-ups, particularly in process-type industrial applications. Whenever seasonal influences are present though they should be accommodated first via the most suitable production strategy.

The message for operations managers is that a "chase" strategy is the best possible option, despite what the textbooks may tell you. Furthermore, there are various practical measures available to avoid or at least minimize the sort of implementation charges that aggregate planning models just take for granted, such as "hiring and firing" costs. Likewise, when a pure "chase" strategy really is infeasible, suitably devised tactics concerning what precisely to put into inventory can reduce the financial risks associated with the necessary stockpiling.

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Appendix

Summary information for each case covers product portfolio; product variety; production mode; minimum labour input; means of achieving volume flexibility; and germane comments.

Chase strategy

(1) *Bulk/bagged cement*; none; for stock, big contracts to order; continuous production; spare capacity at final milling stage; level production of clinker keeps kilns fully utilized.

(2) *Petrol and oils*; ten products from common crude feedstocks; for stock; continuous production; none; export sales (15-20 per cent) maintain critical facilities at full utilization and product mix adjusted to match seasonal demand patterns.

(3) *Industrial paints and varnishes*; approximately 400 types; to unique order; two shifts; overtime; production of some orders can be pulled forwards.

(4) *Domestic paints and finishes*; 417 SKUs from 28 types, colour range, five can sizes; for stock; one shift; increased manning levels, overtime, second shift; JIT production.

(5) *Beer*; two types; for stock; two shifts; sufficient normal capacity for predictable summer weather but overtime available for heatwave; in winter, some idle time accepted.

(6) *Ice cream*; 102 SKUs including flavours and packaging; for stock; one shift but spare lines; increased manning levels, overtime, second shift, then weekend overtime; in winter some idle time accepted for small core workforce.

(7) *35 mm photographic films*; 21 families and 150 packages; to intra-company order (unique packaging); three shifts; weekend overtime; if necessary, customers will accept orders a month early – domestic and export sales patterns tend to cancel each other out – JIT production.

(8) *Ladies' wear*; 500 styles compounded by fabrics and sizes; to unique order; one shift, not all lines manned; parallel six hours shift with workforce increased in steps; counter-seasonal styles and modifications – order book priority juggling – some idle time accepted for regular workforce.

(9) *Ladies' footwear*; winter range 287 styles, summer range 100 styles, in 60 colours, eight materials and different sizes; to order; one shift; orders pulled forward, overtime, up to four subcontractors used for stitching; no room to expand capacity – natural attrition allows workforce to be reduced slightly in troughs but some idle time accepted too.

(10) *Tumble dryers*; ten domestic models; for stock; ten (low-volume) export "specials"; to order; one shift; increased manning levels; excess workers transferred to larger (non-seasonal) washing machine facility – JIT production.

(11) *Lawnmowers, edgers, outdoor vacuum cleaners*; eight models; for stock; one shift plus a small, selective second shift; increased manning levels, overtime, second shift; JIT production.

(12) *Refrigerators*; many models based on 15 cabinet sizes, three brands, three colours; for stock; one shift; increased manning levels; JIT production.

(13) *Electric wall heaters*; 30 models; for stock, one shift; increased manning levels, overtime, second shift in assembly; JIT production; subcontracting to maintain level work load in engineering workshops.

(14) *Nail plate products for building industry*; 800 items in 60 family groups; for stock; specials (and exports); to order; one shift; increased manning levels; core workforce supplemented by skilled packers available at short notice from labour hire company.

(15) *Jewellery*; approximately 1,200 standard items plus occasional custom orders; most items to order, some higher-volume, cheaper lines for stock; one shift; increased manning levels and (home) subcontractors for assembly work; deals offered to buyer groups to smooth order profile.

(16) *Greetings cards and related products: everyday cards*; 2,500 designs; for stock; seasonal cards; 1,000 designs for Christmas; for stock, but 95 per cent pre-sold; specials; to order; two shifts; overtime; everyday card sales 2-2.5 times greater than seasonal cards and specials account for 30 per cent of workload.

(17) *Crumpets and scones*; one type each, some customized wrappers; to order; one shift × two days, not all lines running; increased manning levels, overtime, up to three shifts × six days; product shelf life of five days and sales vary according to day of the week.

(18) *Meat pies, pasties and sausage rolls*; 30 items; to order; two shifts × 6.5 hours × six days, staggered for different processes; increased manning levels and flexible shift lengths; products have short shelf life and sales vary according to day of the week.

(19) *Toys*; 25-30 items made locally but most imported; for stock; local production is subcontracted out; contract arrangements provide the necessary process and volume flexibility; with contracts the biggest problem is to get sales forecasts right.

Modified chase strategy

(20) *Reinforced garden and industrial hoses*; 50 types; small orders supplied ex stock but major customers supplied to order; one shift, not all lines running; increased manning levels, overtime, up to three shifts × seven days; limited stockpiling in company warehouse preferred to Sunday working, but renting outside storage is the last resort.

(21) *Ice cream*; 240 SKUs including flavours and packs, 30-50 families; for stock; two shifts but not all lines running; increased manning levels, overtime; limited stockpiling necessary due to restricted capacity to train employees.

(22) *Processed foods*; 300 items, including container sizes; for stock; one shift, not all lines running; increased manning levels, overtime, second shift; stockpiling necessary for products made from seasonal crops.

(23) *Chocolate Easter eggs and Christmas novelties*; 300 items, including 75 per cent that are customer specific (usually the packaging); mix of make for stock (70-80 per cent of year's forecast sales) in initial batch and make to order (the balance) in second batch; two shifts, not all lines running; increased manning levels, three shifts in critical areas; stockpiling necessary due to equipment constraints, but all production scheduled as late as possible.

(24) *Pine landscaping products (borders, pavers)*; four types, nine products; for stock; one shift; overtime, second shift × six hours, more overtime, local subcontractors top up supplies to furthest distribution centres; subcontracting saves capital equipment and transport costs.

(25) *Surfers' wetsuits*; 50 models in 12 sizes; for stock, but 45-70 per cent pre-sold (indents); one shift; labour turnover trims workforce in troughs (a little) overtime; counter-seasonal product modifications – limited stockpiling within each season maintains labour productivity.

(26) *Boardshorts*; five types, 40 fabrics and 20 sizes; to order; one shift; labour turnover trims workforce in troughs, overtime; JIT production – indent orders pulled forward to maintain labour productivity – counter-seasonal styles and products, exports to northern hemisphere.

(27) *Pharmaceuticals (creams, liquids and sterile products)*; 600 items including packaging, 400 product types; own products for stock, contract manufacture (35-40 per cent) to order; one shift, not all lines running; increased manning levels; overtime, the 60 seasonal items do not peak in same months – level production over immediate three months horizon after juggling contract order priorities.

(28) *Bulk/bagged fertilisers*; one basic type manufactured and one imported to blend 3,000 products; to order; two shifts × 12 hours × three days in production and 1 × 8 hours shift in mix/dispatch; up to six days production via overtime, and up to three shifts in mix/dispatch by increasing the workforce; some (intermediate) stockpiling of basic fertiliser necessary due to capacity constraint.

(29) *Bicycle safety helmets*; ten models, five colours, three sizes; for stock; one shift; increased manning levels; limited stockpiling avoids running second shift.

(30) *Garden tools, axes and block splitters, and other (non-seasonal) hardware*; 2,500 items; for stock; two shifts; overtime in components area, overtime then third shift in assembly to chase MPS; some stockpiling of components necessary due to a skilled labour constraint.

(31) *Ammunition*; 260 items, belonging to smaller number of families; two and three shifts depending on process; mainly for stock, but approximately 40 per cent of output to order (exports and low-volume industrial range); overtime; capital-intensive facilities kept fully-loaded by pulling forward long lead time orders.

Level strategy

(32) *Motor vehicle batteries*; four sizes; for stock; 2 × 12 hours shifts on six days; marketing discounts prices to achieve sales targets.

(33) *Colour television sets*; 12 models; for stock; one shift; overtime used during pre-Christmas peak to compensate for sales forecast errors.

(34) *Cricket balls*; four models; for stock, one shift; customer credit extended for early orders.

(35) *Motor car radiators*; six OE models; to order; 1,200 catalogue items for general aftermarket (mainly cores); for stock; 300-400 older model cores; to order; one full shift plus one small shift; flexible manning on second shift relieves bottlenecks.

Demand management strategy

(36) *Cooling fans and electric strip heaters*; six models each; for stock but >60 per cent pre-sold to major customers; one shift; when regular employees switch to heaters line a temporary shift hired for fans line; JIT production – a New Zealand company took over fans plant and introduced its heaters.

(37) *Gas barbecues*; 70 types expanding to 200 with finishes and options; *solid fuel heaters*; ten models; for stock; one shift plus constant overtime; more overtime and equipment gradually switched from one product range to the other (tool changeovers); company's retail chain stimulates sales via discounts and promotions.

(38) *Evaporative air conditioners and radiant gas heaters*; five ranges each, leading to 165 model variations; for stock; two/three shifts in components production and one full plus one part-time shift in assembly; increased manning levels as up to six assembly lines utilized, including two that can switch between air conditioners and heaters to chase demand; JIT production – company bought a heater plant and transferred equipment to the air conditioners facility.

(39) *Lawn bowls*; 650 models combined with 2,000 decorative patterns; domestic models for stock, exports and Australian "specials" to order; one shift; level production; company has 85 per cent of world market and uses exports, plus limited anticipation stocks of models for Australia and Britain to smooth demand.

Remaining strategies

(40) *Marine distress flares and fireworks*; two types of flares; for stock; one shift; increased manning levels; a stable (core) workforce policy implemented by scheduling all fireworks (20 per cent of total production) in slack period and making maximum use of (restricted) storage capacity.

(41) *Wood heaters*; 12 models in two colours; for stock; one shift; overtime and enhanced performance rate, some press shop work subcontracted out; under a stable workforce policy, and with insufficient warehouse capacity to level production, some idle time is accepted – welded units stockpiled but final assembly scheduled during peak season (purchased components like electric fans are expensive).

(42) *School uniforms and club/corporate wear* (ties and tie fabrics, scarves, pullovers, tunics, blazers); custom designed; to order; one shift in labour-intensive areas (cutting, making and finishing) and two overlapping shifts in capital-intensive areas (weaving and knitting); reducing the degree of shift overlap so equipment runs for longer; strategy encourages school uniform (60 per cent by volume) indent orders and uses them to level production as far as possible – in sales trough assign training and non-production tasks and reduce workforce by labour turnover.