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Addressing Food Production Planning and Control Issues through Information Visualisation: An Agile Development

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ABSTRACT

Food manufacturers have a compelling requirement to address their information management needs in relation to the management of variation in their supply chain and subsequent production processes. However, many organisational information systems are not explicitly designed to address variation and uncertainty. The action research project outlined in this paper addresses a gap in the information management literature by showing how visualisation of information aided the efficacy of perishable goods production in a small food manufacturer. A user-centred, agile approach enabled the design and implementation of an integrated, dynamic visual production management system. Underpinned by a new manufacturing strategy, this system provided an information bridge between members of the organisation and in so doing facilitated improved communication and decision making across the company. The outcome of this action research project significantly enhanced the business performance. It is argued that the increased awareness of the actions and needs of others in the factory supported the enhanced efficacy in the production.

Keywords: Food manufacturing, information visualisation, agile development

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INTRODUCTION

The food manufacturing industry is an important sector with approximately 6000 food manufacturers in the UK alone (Food and Drink Federation, 2011). These organisations account for over 15% of UK manufacturing turnover worth approximately £10bn of exports per annum (Institute for Manufacturing, n.d.).

Advances in information technologies and increased competition are impacting supply chains and production planning processes in the sector (Mangina & Vlachos, 2005). As a result, food manufacturers need to be adaptable as variation in demand makes it difficult to predict the production quantities. Producers need to be able to respond to changes in customer orders with deliveries due within hours of the order being placed. Whilst complying with these demands, businesses have to address the challenges of ensuring products are of high quality, low price, and achieved with low wastage. Consequently, the “demands on the decision makers to rapidly interpret complex data are challenging” (Sackett, Al-Gaylani, Tiwari, & Williams, 2006, p. 690). Wrong decisions by managers and operatives due to a lack of understanding have a direct impact on the efficacy of the production process. Output volumes and quality are affected through the under/mis-utilisation of resources, unnecessary mitigation for the anticipated late jobs and excessive job production time from the wrong prioritisation of orders.

Whilst planning is one of the mechanisms that can aid flexibility (De Toni & Tonchia, 1998), planning practice is often not able to make the most of the available flexibility in the food production processes because existing planning systems only partly resolve this issue (van Wezel, van Donk, & Gaalman, 2006). Ramirez, Morales, and Aranda (2012) highlight that:

> One very important element of flexibility is the flexibility of distribution of information. It is vital to the processes of knowledge creation and improvement of organizational performance, because it enables the firm to enhance the options available to reduce uncertainty and to improve decision-making.

To address these issues, this paper argues that one means of supporting communication across different levels of the organisation, and thus achieving flexibility, is through the visualisation of information of the current tasks. Through an action research project we address the paucity of work that considers how visualisation of information can be applied in production management (Sackett et al, 2006; Sacks, Radosavljevic, Barak, 2010). In addition, we add to a newly emerging body of work that combines agile development and user-centred design.

The paper begins with a literature review of the application of information visualisation in food manufacturing. We then explore the complementary nature of agile development methods and user-centred design as a means of designing such systems. The action research approach adopted for this project is outlined. The remainder of the paper follows the action research project beginning by assessing the issues in production planning systems and action taken to address them at Freshcut Foods (FF), a UK-based small-medium enterprise (SME). Finally, we discuss the impact on the organisation and our interpretation of the underlying basis for that impact.

INFORMATION VISUALISATION IN FOOD MANUFACTURING

To address the problems of complexity and volatility in the production environment, it is necessary to improve communication in order that members of an organisation have a shared understanding of the current demands and priorities. Communication about the plan is necessary to ensure current constraints and changes to orders are known and the production team are aware of any unusual situation that needs their attention. Yet, prior approaches lack the necessary information management capability to enable the responsive management of order variation.

At present, shop floor systems have inappropriate levels of information related to the task provided for the user, data inaccuracies, the lack of interoperability between systems and the lack of timely information for operatives exacerbating the issues rather than address them (Stowasser, 2006). Even where organisations are using advanced integrated manufacturing systems, "major problems remain with respect to the interface between the enterprise corporate level and the manufacturing shop floor level" (Panetto & Molina (2008, p. 641). Panetto and Molina (2008) suggest therefore that an *information bridge* is required to facilitate the communication and integration required between the different levels. This bridge can be achieved through visualisation.

Visualisation of information is widely recognised as a means of supporting human understanding of complex situations and problems. As Sackett et al (2006, p. 689) state, "graphical representations can communicate complex information, help understand complicated relationships between multiple variables, uncover information hidden in the data, and solve problems through representations in the form of data structures for expressing knowledge". So, visualisation "allows decision makers to exploit their natural spatial/visual abilities" to understand the interrelationships between the different tasks, the resources available, and the actions they take to expedite a task Sackett et al (2006, p. 689).

Currently, though, production systems are poorly designed and configured because of the lack of user involvement in the design of the system (Stowasser, 2006). So, for the next generation of manufacturing systems to be successful they need to support the knowledge required for effective decision making, have enhanced human–machine interfaces, and adopt methods that would enable the rapid assimilation of knowledge and collaboration (Nof, Morel, Monostori, Molina, & Filip, 2006).

DEVELOPMENT APPROACH

The values outlined in the Agile Manifesto are underpinned by an understanding that continuous attention is required to technical excellence and good design (Cockburn, 2002). This perspective supports a natural fit between agile software development and user-centred design, or user experience (UX) design. There is emergent interest in bringing the concepts together, but as yet there is "a lack of empirical studies of participatory design activities in agile software development" (Kautz, 2010, p. 305). Najafi and Toyoshiba (2008, p. 531) argue that such design practices "can be incorporated into agile development to help to improve product usability with little or no impact on release schedules." In line with Kautz's (2010) study, we considered the user participation and agile processes to be integral to each other not in some way a parallel set of activities. The participatory processes formed part of the sprints. Different participatory techniques were emphasised at different stages of the development. In terms of Muller and Kuhn's (1993) taxonomy of participatory design methods, the approaches in the development fell into three categories.

The first of these participatory categories is 'early stage/designers participate in the users' world'. The observation of employees and processes in situ is an important early stage in establishing the current practices and issues. Discussions with employees about their practices externalise the tacit concepts and thereby extends their cognitive awareness of the current approaches. The tacit understanding of individuals is distinct from the explicitly defined knowledge captured in formal systems (Allison & Merali, 2006). Capturing operational knowledge is an essential part of the requirements stage. Externalization is particularly important where knowledge about organisational practices lies across a team or organisation. As Arias, Eden, Fischer, Gorman and Scharff (2002, p. 349) explain, "in the case of distributed cognition among members of a group, the group has no head, no place for the implicit information about the distribution of knowledge to be available to all members therefore externalizations are critically more important for collaborative design."

The next group of participatory methods are classified by Muller and Kuhn's "mid-stage/users participate in the designers' world." User-centred design involves moving from work as observed to envisioning a new design for how work might be done in the future. The observation stage is arguably more about *problematising* the proposed changes, casting light on the choices to be made to draw out recommendations or influence the nature of the proposals (Voss et al, 2009). Envisioning therefore is a key stage of idea generation, of innovative thinking, which will be influenced by the observation but seeks to identify new ways of doing things, perhaps from knowledge of other options or the creative refinement of current approaches. It is from this envisioning that the requirements are drawn rather than the observation of pre-existing practices. As Voss et al (2009) note this *co-realisation* of requirements and design can exceed anything that an a priori design can achieve.

The final group of participatory techniques from Muller and Kuhn's taxonomy can be classed as "later stage/designer in users' world"—when users test the software to evaluate the version of the system, with feedback informing the next stage of development. Designs will always need to change as our solutions will be bound by our limited understanding of the situation. Our understanding is constrained by our lack of experience in that situation and the assumptions we necessarily make about how we might improve the situation. This iterative process enables learning through on-going collaboration as successful design involves the emergence of new ideas. The learning process is both between users, and between users and designers. As designs are created and tested understanding about the current and potential systems are explicated. Thus the design is co-realised and becomes co-owned. As users learn more about what is possible the development will give rise to new requirements based on the new arrangements (Voss et al, 2009).

RESEARCH METHODOLOGY

Baskerville and Wood-Harper (1998) advocated the use of action research (AR) for information systems research as a means of developing theory through participatory projects. AR was selected here because, unlike other approaches that seek to study a situation without influencing the actors, we were seeking to work with the participants to solve a current practical problem.

In AR the purpose is to change the subject under investigation through intervention. In this approach, we both develop knowledge and improve practice. Knowledge is developed through intervention in specific uncertain situations. Practice is improved through changing the process currently used. Through the focus of an applied project these two purposes are intertwined as we draw on, apply and refine current theory to address the specific needs in the given setting. The researcher brings existing knowledge to bear on the phenomenon through a series of systematic experiments. Action research is a collaborative activity involving researchers and participants working together to improve the current reality in the organisation, thereby informing the wider body of knowledge through a synergistic cycle of reflection on theory and action (Avison, Baskerville, & Myers, 2001). The result of the work is the refinement of the theoretical premises based on the application of the theory in practice.

Baskerville and Myers (2004) outline four pragmatist premises on which the AR methods are based. First, it is necessary to establish the purpose of the action before the project. Here our theoretical premise is that the introduction of a visual production management system based on a form of drum-buffer-rope planning and control would provide an *information bridge* to aid the management of variability and complexity in food manufacturing.

The second premise is that there must be practical action in the organisation. The action here is centred on the design and implementation of the new visual production system. The manufacturing strategy, as instantiated in a production system, was developed within an agile development approach. We considered that this was best achieved through the *co-realisation of requirements* using user-centred design techniques within an agile development process. The project was motivated by the issues faced by FF in managing and growing the business. Throughout the project the solving of the practical issues remained core. Addressing these through the adaption of prior theory ensured the solution was pertinent to the organisation.

Thirdly, theory is informed by this action. We draw out lessons related to how visualisation acts to facilitate the sharing of information necessary to manage variability in production and show that, through this communication, individuals learn to improve the production process; and how the participative user-centred design process fits with the agile development methods to support the creation of a system requiring significant change in the underlying manufacturing strategy.

Finally, the reasoning and action must be situated in the social context of the problem. The researchers acted as participant observers over a concentrated period of two years and then monitored the outcomes over a subsequent period of three further years. We worked with a team of six collaborators from Freshcut Foods consisting of the production manager, managing director, software developer and a subset of factory supervisors. The academic team reflected the dual nature of the project thus supporting the development of theoretical premises from production management and software design. The main roles of the company employees were to provide an insight to the current practices and issues, to participate in the design, development and evaluation of the system, and to reflect on the outcomes to shape the lessons from the study.

The project followed a cyclic process of reviewing the current situation (diagnosing), identifying actions (action planning), implementing them (action taking), evaluating the impact of those actions and then reflecting on the learning (Davison, Martinsons, & Kock, 2004). The agile development method is coherent with this philosophy and provides a framework for undertaking the cyclic reflection and action. Reflection and evaluation occurred throughout the project. Overall, though, we can categorise this project as linear AR (Baskerville & Wood-Harper, 1998) because whilst there were cycles of learning and action taking in the form of adjustments to the manufacturing strategy and related software at the micro level there was one pass through the principle stages of AR at the macro level.

The remainder of the paper outlines the project from an information systems perspective. The detail of the narrative has been constructed from our journal notes, communications, production data and project documents (e.g. manufacturing proposals, software project management data and minutes of meetings) from the period of the project. Subsequent reflections of the participants interpret the data.

ORGANISATIONAL CONTEXT

Established in 1995, Freshcut Foods is a single-site food producer. They moved to new premises with additional production facilities in 2000 enabling them to diversify their range of products. Subsequently, the company manufactures a wide variety of fresh vegetable and carbohydrate products. Products range from the pre-processing of single raw food items to the creation of cooked multi-item mixes. Customers include blue chip food manufacturers, food service customers and major supermarkets.

Orders are communicated to FF via email, facsimile or by telephone. Repeat orders are received daily with varying order levels and lead times ranging from several days to a few hours. Processing lead time is typically 6-12 hours. Raw vegetables are washed and cut by hand by the Preparation (Prep) department prior to cooking. Following roasting, blanching or char-grilling, products are cooled and packed into bulk bags for distribution.

Planning and control in food manufacturing organisations is undertaken using a wide variety of systems with functionality for forecasting, stock management, order management. Local end-user systems were isolated, so communication and frequency of updates was an issue. Consequently, the decision makers—both on the shop floor and in the production management team - were not provided with the necessary information to manage in this environment.

Orders were entered manually into a sales order processing system and then re-entered into the various planning spreadsheets. Despite the efforts to plan the flow of work, FF was suffering the problems that are endemic within the food manufacturing industry. Material wastage was high because of the short life span of materials. Unnecessary wastage was caused by excessive work in progress (WIP) when the food degraded after being stored for too long. The constant updating of orders combined with the need to expedite additional goods to address production corrections meant that plans had a very limited life and production plans were redistributed on an hourly basis. Due to customers changing their requirements with very little prior notice, the constant expediting and spare capacity hidden by building up excessive WIP then not all customers' orders were shipped on time. To address these issues capacity was increased through temporary staffing and thus increasing the cost of production.

The company strategy was to grow its profit through increasing the level of sales from existing customers and by growing market share by taking on new business. To accomplish this aim the company needed to expand the capacity of its production to cater for the additional volume of orders. Spare capacity existed within the current factory setup but this was masked by the current planning and scheduling procedures resulting in orders being declined because of the limitations of the existing planning approach. To be able to increase profits in line with the company's aims the business needed to streamline its production planning processes, so that the increase in sales did not lead to an equivalent increase in operational disruption and costs.

Critical to the success of the company is its ability to service the customer's fluctuating daily needs in a controlled and cost effective manner, servicing these demands whilst minimising business disruption. If demand increased at the rate that the company desired then soon the planning function within the business would be overwhelmed. The project's primary aim was to develop and implement integrated planning and control systems that will effectively manage the growth in customer demand and the associated complexity. This primarily focused on the fast response needs of the production function ensuring levels of service performance exceed 99% (level prior to the project 97%).

ADDRESSING FOOD PRODUCTION ISSUES THROUGH AGILE DEVELOPMENT

In our action planning, we advocated that the above issues in production management could be addressed through improved visualisation of the current situation based on new manufacturing strategy, and that this concept could be implemented through user-centred agile methods. The conceptual manufacturing strategy adopted by FF during this project was based on a drum-buffer-rope (DBR) concept for scheduling, which was developed by managing variation and focusing improvement activity on reducing variation (Goldratt, 1990). This approach lent itself to visually representing the task status.

The need to overtly manage inventory and capacity buffers in order to protect the delivery system from the impact of variation and uncertainty forms the core of this work. The left hand side of Figure 1 shows a traditional DBR design, in which the roasting and char grill processes would be the constraints (drums). The constraints determine the pace of the delivery system and take the form of a detailed schedule with the material release schedule being created by applying a lead time offset (the rope). The buffer is sized with the expectation that only 5-10% of the products will penetrate the final third of the buffer (red zone) indicating the need to take corrective action to ensure timely delivery. Gathering data on the repeated causes of delay enables common causes of variation to be addressed.

The DBR idea is developed further in Simplified Drum-Buffer-Rope (SDBR) so that the drum is assumed to always be the market demand (Schragenheim & Detmer, 2001). This simplifying assumption is consistent with many markets where there is an implied commitment to match ongoing demand and, therefore, to find the capacity required rather than refuse orders based on any capacity limits. On this basis, SDBR was used to form the manufacturing strategy for Freshcut Foods (Stratton, Robey, & Allison, 2008). The rope (initially set at 48 hours) triggers the release of materials to whichever department is first in the product's routing chain. By implementing SDBR the release of material from goods-in was limited to avoid the over production of WIP ahead of the demand.

The SDBR system is illustrated on the right hand side in Figure 2. The buffer is a division of the rope time into equal thirds, with red being the final third before the product is due to leave the factory. On the factory floor each production department will view the statuses of released orders, prioritised by buffer penetration. As a department finishes work on a product it 'checks off' that it has completed this item highlighting that this product is now available for the next department to begin work on. Buffer management prioritises the order sequence and urgent orders enter the system based on their dispatch times, being expedited to the front of the schedule where appropriate. Such orders need to be visible so downstream departments can see them and thus can prepare for their arrival.

The development of the system followed the concepts of agile development with user-centred design as outlined above, drawing on Scrum as an iterative product development process (Schwaber & Beedle, 2001). Each period of implementation (known as sprints in Scrum) tackles the requirements in order of importance. User participation was both direct and indirect in nature: production managers and shop floor supervisors directly interacted with the designers to communicate their requirements, but they also acted as surrogates for shop floor operatives; shop floor operatives were directly involved in the observation and testing stages.

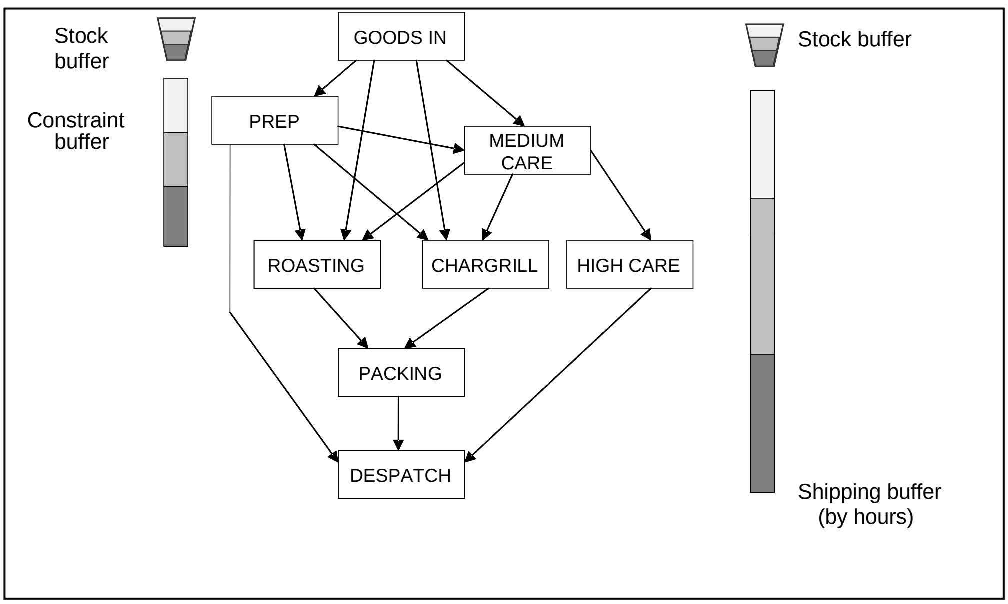

Figure 1: FF General Processing Areas and Sequence.

At the beginning of the project, the initial conceptual development involved significant observation and shop floor level enquiry to discover how the current system operated, gathering any obtuse requirements in the process. The lead developer spent time as an operative: both as a means of learning the processes and to be assimilated into the shop floor team, thus improving communication and building confidence in the development process. Additionally, time was spent over a three month period undertaking ethnographic observations of the production processes and the creation and use of information in production. This period cast light on organisational norms and habits, and the perceptions of the operatives about the current approaches. The problems identified helped our understanding of how to improve the effectiveness of the process. These were noted and used in the justification of the new approach.

TODAY'S DATE: 30th May CURRENT TIME: 10:25

CURRENT PRODUCTION SCHEDULE

CUSTOMER	PRODUCT	ORDER QUANTITY (KG)	DESPATCH TIME	☑
Pizza Factory	Roast Red Pepper Strips 12m	90	TODAY - 15:00	☐
Pizzeria	Steamed 5mm Mushrooms	85	TODAY - 15:00	☐
Katies Kitchen	25m Red Pepper Segments	270	TODAY - 15:00	☐
Buckingham Foods	Sweet Potato Mash	10	TODAY - 15:00	☐
Brambles	20m Roast Parsnip	40	TODAY - 15:00	☐
Katies Kitchen	3 Peppers Mix 25m Hand Grid	10	TODAY - 19:00	☐
Yorkshire FS	10m Slice Potato	150	TODAY - 19:00	☐
Pizzeria	110m Courgette Tongues	25	TODAY - 19:00	☐
Pizzeria	25m Red Pepper Segments ½'s	25	TODAY - 19:00	☐
Heinz	Rst Cherry Tomatoes	50	TODAY - 21:00	☐
Geest Eden	Canadian Chick Peas	500	TOMORROW - 09:00	☐

Figure 2: Example Process Screen Mock Up.

An agile process assumes that requirements will change during the period between initial specification and delivery of a product. However, there was a high level of uncertainty in the business requirements due to the radical change in the manufacturing strategy; so this risk was managed by undertaking an initial low cost envisioning exercise. The vision for the application of a new manufacturing approach through a dynamic, visual system was created initially by the researchers and enhanced collaboratively with the wider agile team. This envisioning stage encouraged a debate about the ideas and how these would address the core issues the company were facing. So, in line with Voss et al (2009, p. 49), we found the requirements arose out of the interplay between the current work practices and the future technological, political and organisational possibilities (and constraints). Simple mock ups (such as in Figure 1) and story boards were used to demonstrate the ideas as they formed. The SDBR conceptual design was the foundation for this work. However, agreeing these requirements was not without its challenges. Convincing the participants that the SDBR concepts would actually improve the organisation's capacity and that the solution was technologically feasible was not straightforward. A series of external visits, educational seminars and simulation exercises helped but resistance remained. On occasions the reversion to traditional approaches of production management were discussed. However, the team persisted. A pilot stage was agreed to test the concepts.

A prototype was created to continue to flesh out the requirements from the storyboards. The prototype encapsulated requirements to have real-time updates in all production areas, prioritisation and scheduling of work orders, and rescheduling orders as the situation changed. The prototype provided a proof-of-concept to evaluate the concepts cheaply, using simple dynamic applications in MS Office products. The use of the prototype as a pilot was a formative learning process: both for the developers and between the various users. This helped the key influencers to begin to realise how the new concepts would help. So as the design evolved the final design was created from an appropriate amalgamation of the external knowledge base and internal understanding of how it could work in this context. Indeed improvements to the concepts were developed with the users during this stage. For example, a simpler means of sequencing the order on the oven and char grill was conceived and devolved to the departmental level.

The initial requirements identified in the prototype formed the product backlog for the factory level version. The requirements were defined as user stories. Each sprint delivered a set of features from the product backlog. The initial product backlog was expanded into user stories at a more detailed level of functional granularity. As part of the development appropriate elements of the prototype were refactored to save effort. The final version of the system utilised a visual programming language with a rationale database; these were integrated with the organisation's enterprise management software.

The Scrum meeting was a valuable tool in crystallising stakeholder opinions, helping staff to become accustomed to and develop a consensus about the new manufacturing strategy. So, evolution of the design, early results and an opportunity to shape the implementation were all helpful in resolving tensions between the various stakeholders. These discussions aided the ongoing refinement of the strategy; but also the development of a consensus and the emergence of a new understanding of how the company would operate. So the assumptions were refined as the development unfolded, such as a reduction in the buffer from 48 to 36 hours. Seven sprints were conducted prior to the first shop floor release, with additional features being added to the backlog lists at the end of each sprint as the review sessions were held.

The final design was web-based and involved an interface with the sales order processing system and the installation of terminals on the shop floor. An example SDBR screen layout used by management and the shop floor is illustrated in Figure 3. This followed on from the mock up in Figure 1. This figure shows the orders in buffer priority order and is colour coded to display the three buffer regions (green, yellow and red). Where an order displays a negative buffer it indicates work has been released in advance of the planned 36 hour rope, which would normally warrant questions over why this was necessary. When an order enters the system it is prioritised appropriately. The system refreshes frequently to maintain near real-time status. So such high priority orders are automatically highlighted and made visible to the current department with subsequent departments being made aware of their imminent arrival. The final version is outlined and evaluated below.

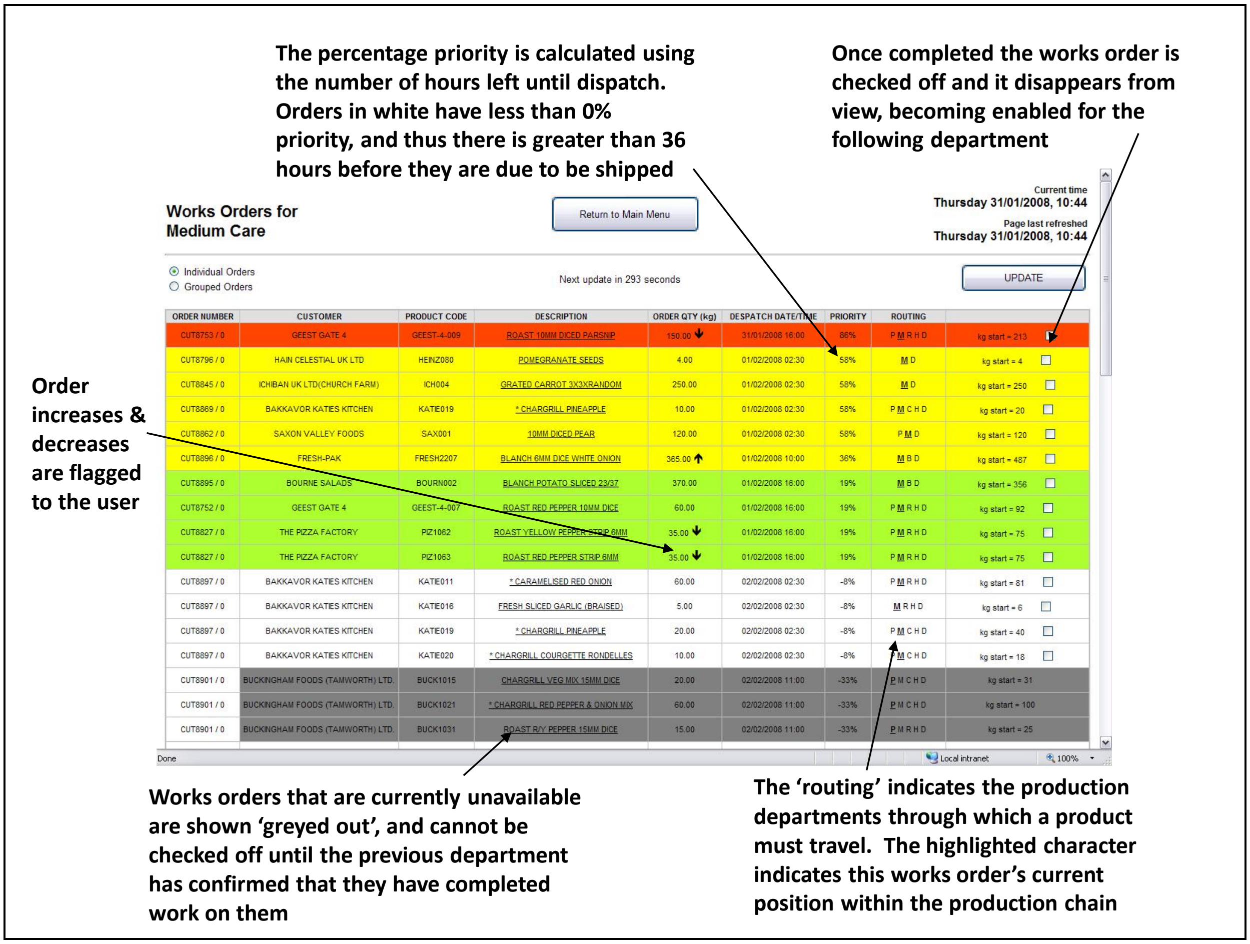

Figure 3: Typical Production Screen Layout Displaying Orders in Buffer Priority Order.

EVALUATION AND DISCUSSION

The project explored how user-centred design approaches fitted within the agile methods and how through this users and developers learned how to design a solution that endorses the local worker's position as decision maker. As systems designers we needed to engage reflexively with regard to the images and accounts of working practices provided by users and those we created. Designing the user experience through a participatory approach encapsulated in agile software development involved not just visual design, but also understanding the whole interaction between human and technology to ensure a desired outcome. The engagement across organisational groups and hierarchy helped to address the potential for one perspective to dominate, and thus to focus on the communication of information between parties. The use of external knowledge as a basis for a new approach had the effect of challenging preconceived views of how the processes should operate. By working through the agile user-centred practices the solution evolved to consider how the theory and system would work in the physical and social environment of the factory.

The system provided an information bridge that enabled communication of activities in a dynamic and visual fashion – between levels and between operatives. With this system, local decision makers could exploit their knowledge of the products and resources to utilise the capacity available in the organisation more effectively. The individual operatives were able to maintain an understanding of the current situation across the factory, both upstream and downstream, and therefore react accordingly. The interaction between the operative and the information system enabled the fluctuating situation to be addressed locally rather than attempting to define the all rules explicitly in the system.

The importance of the dynamic, social element in the sharing of knowledge we observed should not be underestimated and deserves further study. Whilst recognising that knowledge resides with individuals, a shared understanding of the job requires relevant information to be expressed and communicated to others. The visualisation of the status information provided an immediate awareness of the changes in the system. Operatives and managers gained a greater awareness of the (foreseen or unforeseen) impact of an action on the wider production system. This communication of actions and activities through the visualisation of production and task information enabled the management of this complex situation and the problems of variation within it.

Erickson and Kellogg (2002) use the concept of socially translucent systems to explain how making social (shared) information visible within the system goes beyond simply communicating facts. They draw from the realms of architectural practice, based on the understanding of the interrelationship between physical spaces and social interaction, to identify principles that apply to digital design. So, systems should be designed to make socially significant information visible as humans react more readily to visual rather than textual information.

By making things visible it increases awareness. Awareness encourages and constrains our actions based on our social habits, norms and rules. Visualisation of the fluctuating orders enabled the workforce to be responsive to the changing priorities ensuring the delivery times were met without excessive raw stock or WIP to mitigate the risk of a late order. By understanding the production information the interrelationship between the tasks, resource capacity and the delivery priorities the production team were able to expedite the work to best effect. By observing the flow of production jobs individuals recognised the consequence of their actions. Here the production system design enabled tacit knowledge to be drawn upon in-the-moment of the decisions for the scheduling of tasks. Local scheduling of key resources enabled the tacit understanding of the factory requirements to be amalgamated with the information on the screen.

Through this awareness we are accountable to others. Because we are aware of the presence or actions of others (in this case a change in job priority) we are accountable for ensuring that the job is advanced with appropriate priority. There remains, however, a tension between privacy and visibility: we need to enable the operative to have sufficient independence to enable them to make the decisions appropriate for the local operation where these do not adversely affect the overall efficacy of the process. Operatives understood that if a job is sitting in the red zone for long they are accountable to their colleagues for the potential delay to the delivery. We argue that the visualisation of production work does not constrain competence or knowledge of individual operatives, but enables them to exploit that knowledge more effectively through a shared understanding of the current situation.

	2005	2006	2007	2008	2009	2010	2011
Number of staff	80	80	80	87	95	109	115
Revenue	£4,350,000	£5,000,000	£5,500,000	£6,350,000	£7,500,000	£10,500,000	£11,500,000
Profit before tax	£87,000	£100,000	£200,000	£405,000	£450,000	£234,000	£295,000
Number of product lines	100	130	200	265	300	336	400

Table 1: Business Performance Indicators.

From these changes, the production system achieved the original business criteria and has been a major contributor to the growth and increased profitability. As shown in table 1, FF to took on an increased volume of orders without the proportionate increase in staff and capital spending. The end result enhanced factory production throughput, which has led to a growth in revenue of over 250 percent and relatively lower operating costs and inventories. Wastage was reduced as less food was obsolete in the production process or at the retailer. The system has proved useful in managing complexity enabling a 400 percent increase in product lines. The additional volume was managed with only a relatively small increase in staff resources. Subsequent changes to the system have extended the capability to enable multiple flows through the factory for more complex product mixes. As a result of these improvements the organisation received an “A grade” commendation by the British Retail Consortium.

CONCLUSION

The food industry has a compelling requirement to address its information management needs in relation to the management of variability across production and supply chain processes. The food manufacturing sector has to manage complex, fluctuating demands. This variability calls for specific action in the design of the information systems used in production management. Yet, there is a paucity of work in this field. This action research project addressed the imperative issues for one organisation. The practical outcomes of the project enabled the company to introduce a new visual, dynamic production system based on SDBR concepts. In doing so it grew its business through improved production efficacy. From this project we can draw a number of conclusions.

The combination of agile and user-centred approaches facilitates the co-realisation of requirements. Through this co-realisation the understanding of how the organisation should operate changes so that the final requirements are more appropriate to the real needs. The practices of engagement with the users enabled a shift away from defining the system based on either current practices or externally derived initiatives. Direct engagement with the users goes beyond a Scrum team. User-centred design approaches can be enfolded into the agile development methods. Adoption of these techniques helped both the designers and users to learn about how the system should be designed.

The dynamic visualisation of the production data provided the necessary information bridge between members of the organisation to assist in the communication across the departments, and between the factory and the company senior management. The social translucence of the system enhanced the communication across the factory. In doing so people learned to change behaviours as well as being better informed. This communication and learning enhanced the efficacy of the production flow. Arguably, the efficacy can be related to the increased awareness of, and accountability to, others across the factory as well as the underlying manufacturing strategy on which the design was founded.

This action research project has shown how manufacturing systems can support the knowledge required for effective decision making using visual interfaces. As with all AR projects, the ability to generalise findings from one study is open to question. It only addresses a single organisation's needs and the findings are subject to the constraints of that context. Also it is uncertain whether simply adopting the devised system into a new setting would succeed given that we argue that the co-realisation of the requirements is a factor in the success of the new system. However, the findings related to visualisation acting as an information bridge to support communication was replicable across the units at Freshcut Foods, even though there was a diverse level of engagement with the design process across the units. Further application of the techniques adopted and the visual production management system in other contexts is required to further evaluate them.

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