KES Transactions on Sustainable Design and Manufacturing I
Sustainable Design and Manufacturing 2014 : pp.1073-1086 : Paper sdm14-061

OPEN INNOVATION MODELS FOR KNOWLEDGE DRIVEN FOOD AND PACKAGING MANUFACTURING

Panagiotis Tsimiklis, Sheng Feng Qin, Stephen Green,
Tom Rodden, Sharon Baurley, Charalampos Makatsoris*

School of Engineering and Design, Brunel University London, UK
*Corresponding author, e-mail address: harris.makatsoris@brunel.ac.uk

Abstract: Closed innovation approaches have been employed for many years in the food industry. But, this sector recently perceives its end-user to be wary of radically new products and changes in consumption patterns. However, new product development involves not only the product itself but also the entire manufacturing and distribution network. In this paper, we present a new ICT based framework that embraces open innovation to place customers in the product development loop but at the same time assesses and eventually coordinates the entire manufacturing and supply chain. The aim is to design new food products that consumers will buy and at the same time ensure that these products will reach the consumer in time and at adequate quantity. On the product development side, our framework enables new food products that offer an integrated sensory experience of food and packaging, which encompass customization, healthy eating, and sustainability.

1. Introduction

Two of the *key challenges* that face the food manufacturing industry include the ability to identify market segments that have different sensory needs, and the ability to respond quickly to these segments. Nowadays, new food products must offer an *integrated sensory experience of food and packaging*, which encompass *customization, healthy eating, and sustainability.* Although, one could argue that the food industry is an active industry, with roughly 3,500 new products reaching the UK retailer selves every year, at the same time, it suffers from massive Research and Development waste, as 80% of those new products are expected to fail within the initial two years since their launch onto the market and hence, they cannot provide a decent return on development investment. A key reason is that traditional New Product Development techniques do not obtain unbiased inputs from consumers who are not involved in the loop of those techniques *[4, 12].*

By embracing Open Innovation models to interact with consumers at the place of product consumption, we can discover new market segments and understand their needs. Then, by integrating new product design, production and business systems in an ICT platform, smart and on-demand manufacturing networks´ configurations and demand allocations can be generated. By obtaining that piece of information, we can rapidly, economically and sustainably respond to those new market segments.

In this paper, we present such an ICT-based framework that integrates new consumers, with new product development and manufacturing into a seamless process. Simulation and optimization models will enable expert users to discover the manufacturing capacity of any available installation, configure manufacturing networks and processes, select appropriate suppliers and assess risks associated with particular process and network configuration decisions in responding to those new market segments. Embedded in the models will be sustainability considerations such that compliance with environmental as well as business strategy is attained.

2. Approach/Model

The food industry is a mature and slow-growing one and is typically very conservative with the level of investment in new technology. At the same time, it is a very active industry constantly seeking to identify and address the needs of new market segments, although innovation is restricted to incremental improvements of existing products.

The traditional closed innovation has been used for many years within the food industry. But, this sector recently perceives its end-user to be wary of radically new products and changes in consumption patterns. Such perceived wariness, together with the restricted legal requirements related to food safety, transforms food industry's innovation process into a highly complex, time-consuming and risky "odyssey", and hence one not to be lightly undertaken.

However, these recent important changes in the nature of both food demand and supply, coupled with an ever-increasing level of competitiveness, and the high volatility of global markets caused by the global financial crisis, have rendered innovation not only an unavoidable corporate activity, but also one that is increasingly vital for overall profitability and survival *[5, 6]*.

2.1. Challenges of the Food Industry

According to *[10, 11]*, the UK Food Industry contributes GBP 80Bn to the UK Economy and represents the 7% of GDP. Furthermore, Food Industry employs 3.5 million people in 196,000 enterprises of all sizes in the UK alone. But, the industry is globally facing the following key challenges:

1. the International Financial Crisis *[9]*,
2. global population is expected to increase by 9.1Bn in 2050 *[10, 11]*,
3. global resources (energy, water, land) are rapidly being used up *[10, 11]*,
4. the fact that in developed countries, the mean number of members of a family is getting less *[21]*,

5. the "single" consumers prefer ready-to-use products in individual formats *[20]*,
6. the reluctance to embrace new technology leads to missing on potential added-value opportunities *[5, 6]*,
7. the commodity products are typically low profit margins ones *[5, 6]*,
8. consumers of undeveloped countries cannot afford to buy huge format packs *[22, 23]*,
9. the new international labelling system requirements for the primary packaging *[24]*,
10. the necessity for a more flexible world-wide distribution *[16]*, and
11. the demand for new products to be sourced, produced and delivered by sustainable way *[11, 19]*.

However, within the next fifty years, the biggest challenge that the food industry is going to face is that it is expected to produce more food than that has been produced in the entire history of humanity to meet the global demand *[19]*.

2.2. Embracing Open Innovation Models

Open Innovation is defined as the purposive use of knowledge that exists both inside and outside any organization. That mixture of knowledge can speed-up the time-to-market process, enrich the internal innovation environment and expand any company's market frontiers far beyond to new market segments *[1]*. Nowadays, Open Innovation *[1, 2, 3]* has been commonly associated with fast-growing industries, like the information and communication technology sector or the pharmaceutical industry. There is, however, increasing evidence that this concept may also prevail in more traditional and mature industries as the food industry *[5, 6, 7, 8]*.

Although Open Innovation *[7, 8, 9, 12]* is one of the most debated topics in actual global literature, the majority of the studies are broad and there are still many questions that have not been answered. One of them is the link between the corporate Open Innovation practices and the food industry manufacturing structure.

Open Innovation offers a new approach to involve consumers in the loop and enable the design and production of food products that are desired and will actually be consumed. However, in contrast to the current application of Open Innovation which mainly relates to the closer engagement and involvement of suppliers in corporate R&D, our Open Innovation model embraces crowdsourcing technology to place the end consumer in the New Product Development loop. This is a way to mobilise and obtain more fine grained perceptions from consumers in order to identify and define more precisely discrete market segments and as a results, we can accelerate New Product Design (NPD) and make the process more efficient within that mature industry *[4,12]*.

The proposed ICT platform comprised of digital media and information management tools that enables an integrated product experience encompassing:

- Customisation – building and blending your own food
- Being involved in food manufacture – having ‘conversations’ with brands
- Social aspects of eating & sharing – people congregate around shared affinities; gift giving; sharing knowledge
- Nutrition & health - supporting individual nutritional needs according to lifestyle and goals
- Sustainable & ethical issues relating to food sourcing, packaging design

Once that part has been created, we propose to use information management tools to re-configure manufacturing lines in order to respond quickly to emerging market segments.

To reach that point, we need to integrate design, production and business systems with the mentioned platform. Then, *we should study simulation and optimisation models and techniques* which can be used by expert users to discover the manufacturing capacity of any available installation, configure manufacturing networks and processes, select appropriate suppliers and assess risks associated with particular process and network configuration decisions.

2.3. The Framework

Placing customers in the loop is a major change for most organisations that demands new thinking in developing and operations strategy. Operations Strategy is concerned with the choice of pattern of strategic decisions and actions which determine the role, objectives and activities of the organization *[13, 14, 15, 16]*. There are the five basic performance objectives and they apply to all types of organisation:

1. Quality: consistent conformance to customers' expectations.
2. Speed: the elapsed time between customers requesting products and their receiving them.
3. Dependability: delivering or making available products when they were promised to the customer.
4. Flexibility: the quality of being adaptable or variable.
5. Cost.

Agile operations management aims at addressing those five performance objectives and is a central component to our framework. Agility *[17]* is defined as the ability of a system to rapidly respond to change by adapting its initial configuration. It is the ability that combines and adopts any business system to any of all those 5 objectives.

Agile Manufacturing (AM) *[17]* is a company-wide strategy that pursues to respond well to unexpected change in all aspects of a company’s operations. We can define it in two contexts:

• *Externally*, as perceived by customers: (AM) means responding to those customers' needs by rapidly designing and manufacturing products customized to those requirements.

• *Internally*, in terms of a company's own operations, (AM) focuses on reducing the lead times for all tasks in a company, resulting in improved quality, lower cost, and of course, quick response.

Figure 1 shows a scenario using Internet/Intranet networks to speed up information flow in a product development cycle and thus to achieve reduced development time and costs.

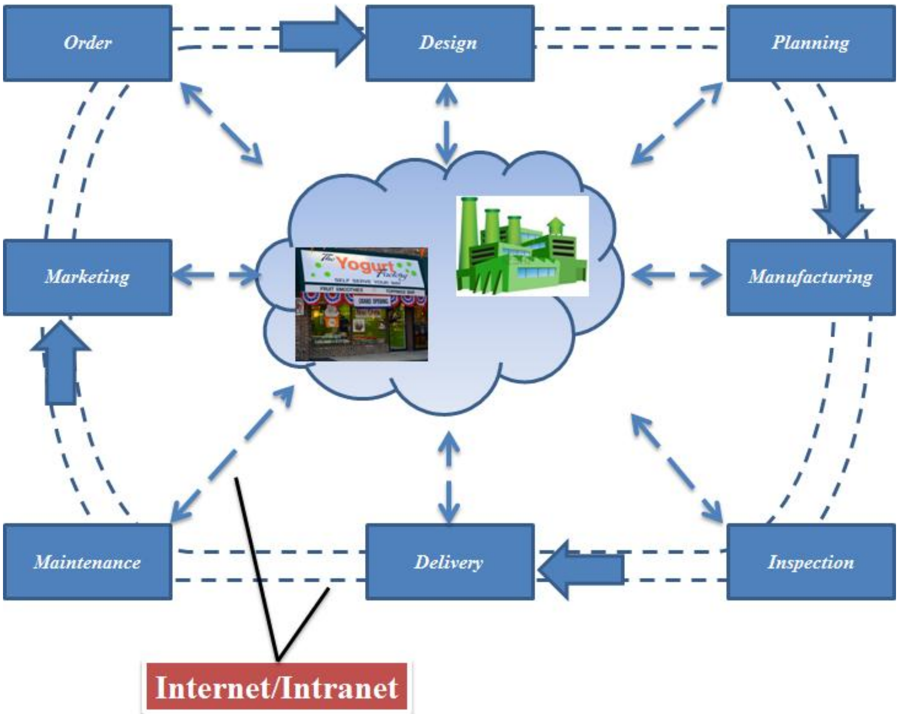

Figure 1: A scenario of using Internet/Intranet to support information flow in product development cycles.

Traditionally, however, efforts in the application of agile frameworks have been focused on shortages of traditional energy sources and their price fluctuations, the need for more energy - efficient products or products using alternative energy sources - is clear. Opportunities exist to re-engineer many industrial products based on new ratio of energy costs and capital costs. New energy - conservation concepts and service - will be needed. The design and marketing of this range of products are challenging because of price fluctuations.

Changes in energy availability and prices are but one example of the many possible futures we face. The many changes in the status quo present problems for unchanging organisations but represent real opportunities for those organisations that adapt and evolve with new market offerings. The organisations that will not just survive but thrive will use a learning organisational concept with which will examine their role in society and our continuously changing environment. One of the important rationales for their existence is based on innovation and agility to fill societal and customer needs.

In the food industry to place the customer in the product development loop entails the capturing and translation of those external signals from the market into actionable information by the organization. But, how we can relate those external signals from the customers with the internal situation of a manufacturing organization?

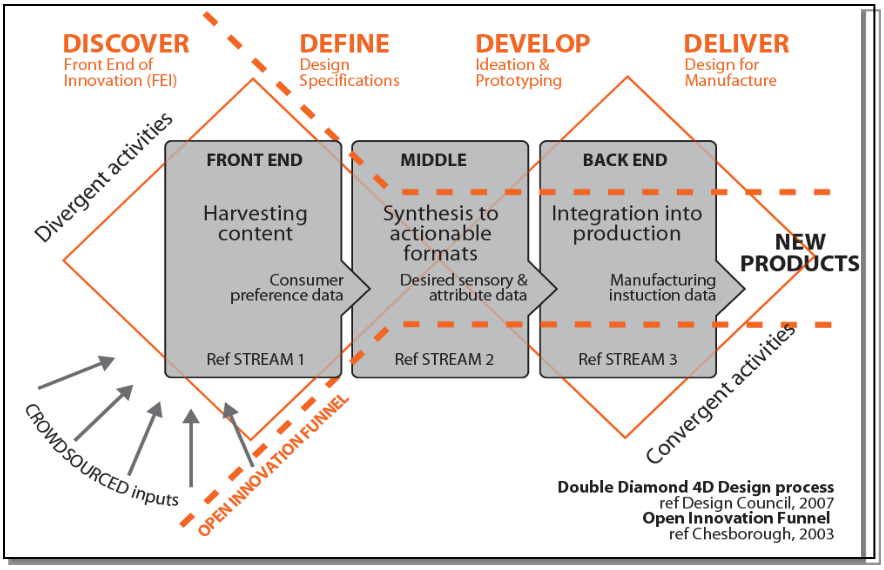

Figure 2: The relationship of open innovation with the double diamond 4D design process model.

It is our framework, in Figure 2, that has been designed to address this challenge. Our framework combines the UK Design Council's Double Diamond 4D design process and its steps of Discover, Define, Develop and Deliver *[18]* with Chesborough's Open Innovation Framework *[1, 2, 3]*.

Our framework comprises three information processing streams. The first stream is the **Front End** of the model, which comprises a crowdsourcing interface for *harvesting* attitudes/perceptions from consumers. It achieves that via a combination of both on-line and off-line modes of interaction. By having in mind that one half of all local searches are performed on mobile devices and 60% of population sleep with their phones *[7, 8, 9]*, we can easily understand why the term *crowdsourcing* at that step is really more adequate. The term as itself describes a new web-based business model that harnesses the creative solutions of a distributed network of individuals through what amounts to an open call for proposals. In other words, a company posts or identifies a problem or a new idea online, a vast number of individuals offer solutions to that problem or idea, the winning solutions are awarded and developed and, finally, the company mass produces that idea for its own gain.

The second stream in the **Middle** is crucial for mapping the raw and usually very abstract inputs from consumers to actionable customer requirements. This stream combines data visualization with machine learning techniques to achieve that and provide specific design attributes for a new food product such as texture, rheology, viscosity, colour etc. from the sensorial preferences extracted from the crowds, to the **Back End.** This last stream is responsible for translating the consumer requirements into product specifications and ultimately determining the manufacturing and distribution instructions to satisfy the markets identified in a sustainable and economical manner. Simulation and optimization are crucial components of the Back End that are used to assess feasibility of manufacturing and supply and prepare plans to coordinate the entire supply chain.

3. Case study and Discussion

The case study concerns the development and manufacture of yoghurt. As shown in Figure 3, it is a complex multi-dimensional project that requires many considerations and compromises to be made. A key target is to achieve sufficient differentiation compared to competition and this is embodied not only in the formulation of the product itself but also in the packaging and distribution.

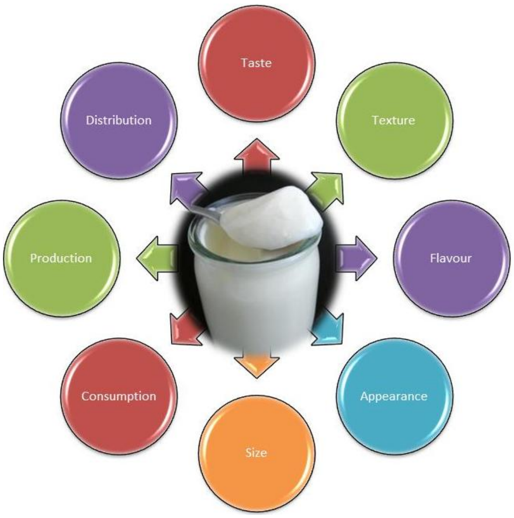

Figure 3: Considerations for yoghurt product development.

Once having done these considerations, harvesting attitudes and perceptions from customers are then the important subjects to be investigated. All that we propose is the integration of “the open innovation funnel” with the “double diamond” 4D design process described above. That is linked to the *Front End* of our model and we can propose some of them:

a. By creating different types of questionnaires focusing on customers´ wants or "*looking for*" and posted on social web-sites,

b. By using specific "web questionnaires" posted on Intranets

c. Or even, the traditional customer-interview questionnaires next to the shops.

The framework presented above, allows the interaction direct interaction with consumers. One of the possible approaches is via the design of the correct questions to crowdsource the responses to. Those relate to the product appearance, taste and packaging (see Fig. 4). For example, for a new yoghurt product, characteristics such as "Light", "Fresh", "Longer Life", "Ecological", "Bio" or even "Lactose Free" are indicators of a clear necessity.

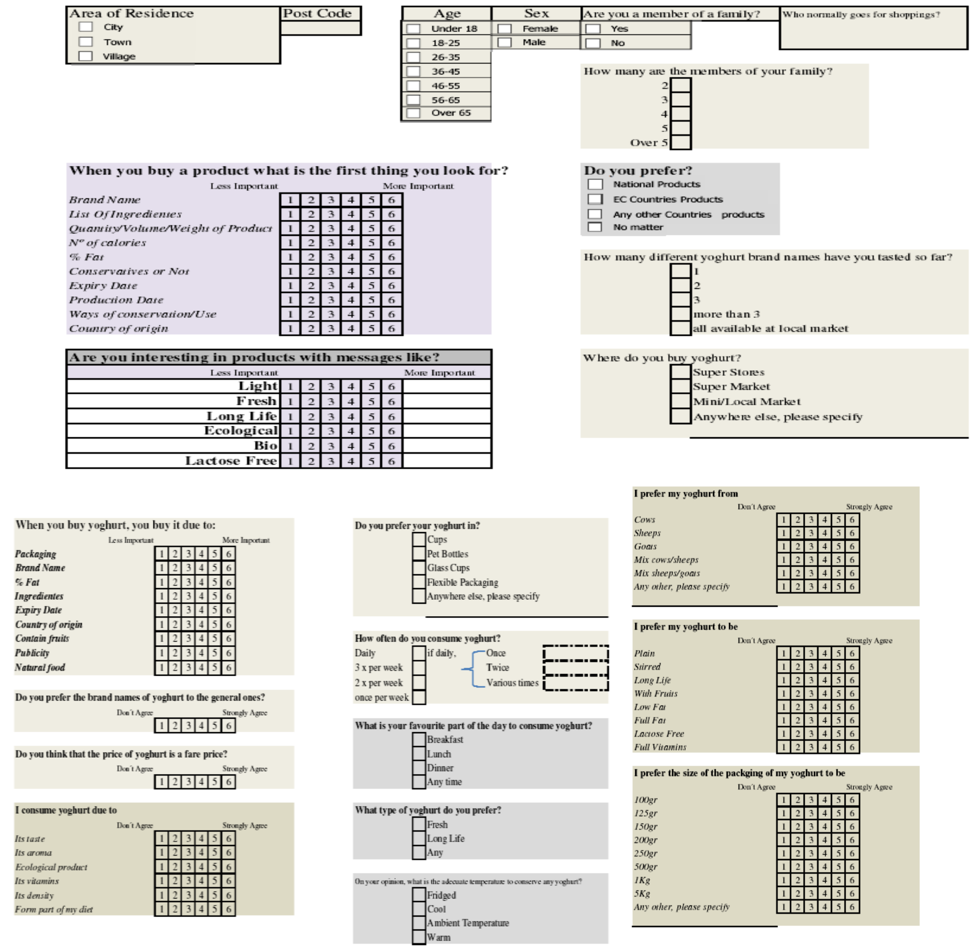

Figure 4: Obtaining Consumers´ inputs.

Those inputs represent what consumers value most. The responses are compared against existing practice and the current knowledge of consumer preferences and market segmentation.

On the process and supply sides, knowledge of available process, manufacturing and distribution capability, ingredient types and availability are taken into account. All those inputs and current knowledge are grouped together and mined for new relationships between the data that could reveal new desired product attributes and market segments. For example for the yoghurt case, the following factors are also considered:

- the International Financial Crisis,
- the fact that in developed countries, the mean number of members of a family is getting less,
- the "single" consumers prefer ready-to-use products in individual formats,
- consumers of undeveloped countries cannot afford to buy huge format packs,
- the new international labelling system requirements for the primary packaging,
- the necessity for a more flexible world-wide distribution, and
- the demand for more and more sustainable products.

All those considerations lead to the following key product targets:

1. The product should be available in an individual format.
2. The size of the primary packaging of the product should be small.
3. The design of primary packaging should be by that way that consumers always perceive a high quality product
4. All legal information must be on the primary packaging in different languages.

A response to those considerations in combination with the inputs obtained from the crowds, leads to a set of basic technological requirements that can be actioned upon. Table 1, shows the requirements for a new yoghurt product.

Initial Technological Requirements:

- Flexible primary packaging: Material, Design, Capacity, Usage, etc.
    1. **Material: PS or PP (with sleever or IML, in-mould-labelling/without sleever or IML)**
    2. **Shape (Design): round, cylinder, rectangular, truncated cone, etc.**
        a) **Split cups (with jam, honey, etc.)**
    3. **Capacity: min., 100g., 125g., 150g., 175g., 200g., max.**
        a) **Cups diameter/Cups Height**
    4. **Other Features: Cups with snap-on-lid**
- Filling Flexibility: product viscosity, temperature of filling, etc.
    1. Fruits, mix of fruits, etc.
    2. 0%, 5%, 10% M.G., Creamy products, etc.
    3. Extra Calcium, without lactose, etc.
    4. Soy products
- Aseptic
    1. Hygienic Design (FDA, etc.)
- Production Capacity: Not so high, but high flexibility
    1. 20.000-35.000 unidades/h
- Format change-over: rapid and highly optimised (1-2h max.)
- Flavour change-over (flavours, mix, fruits, etc.) – rapid and highly optimised (20/30 min.)
- Cleaning procedures SIP/CIP, etc – rapid and highly optimised (20/30 min.)

Table 1: Basic initial Technological requirements.

In the yoghurt case, the design of the primary packaging with all accessory components and characteristics is clearly defined by prototypes, the machinery to process such a kind of packaging and product is also defined by industrial trials and all other aspects such as additional formats, promotional formats, trays, palletizing patterns, etc. that are related to consumers´ wants are clearly defined and prototyped.

Figure 5: Product Prototypes.

At this stage, it is important to mention that agility is a key component for success as all type of machinery should be selected by having that added performance value in mind. For the yoghurt facilities, the specific characteristics of the manufacturing line are:

1. Well-designed planned capacity of the whole production line,
2. excellent production scheduling,
3. automated control of the whole process and production line,
4. quick change-overs, easy to handle different formats of primary and secondary packaging,
5. easy to handle changes in the process plant,
6. flexibility in changing palletising patterns,
7. rapid, efficient and effective CIP/SIP cleaning procedures,
8. Hygienic design for any component, etc.

Those requirements are used to drive product development and the design and execution of the supply chain operations. The framework in Figure 2 embodies the tools for the design and operation of a **smart manufacturing network that ultimately can drive on-demand manufacturing,** where demand allocation and the configuration of the network itself can be determined dynamically, as product requirements and demand evolve. At the design stage, simulation assesses possible manufacturing network configurations and planning algorithms project future execution. The outputs are then set points for manufacturing execution that conventional enterprise resource planning tools can plan against and feeding back actual manufacturing execution progress and exceptions. Figure shows an example scenario of how a demand of 15,000 cups of yoghurt is handled by our framework.

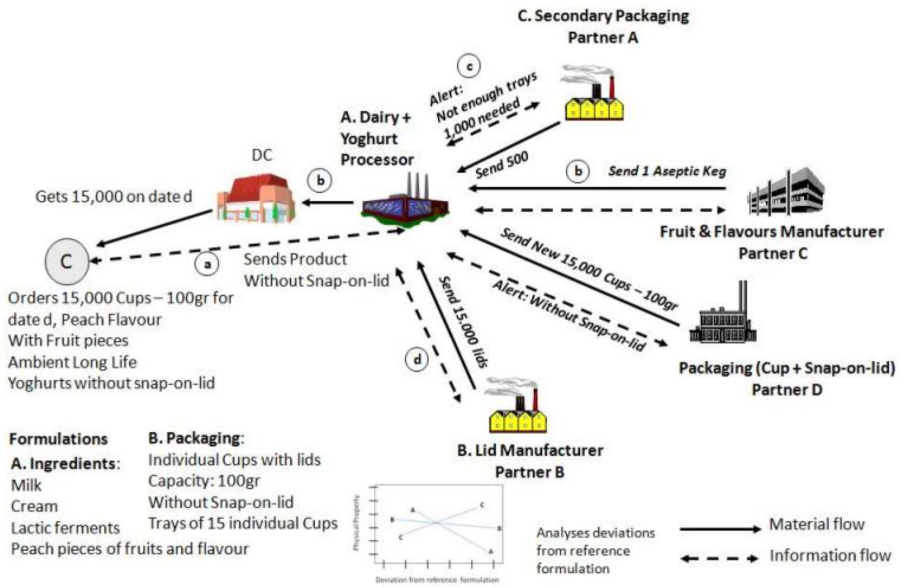

Figure 6: Example Yoghurt Manufacturing Operations.

4. Conclusions and Future research

In this paper we presented an overview of the models employed in an ICT based framework for integrating processes with people to integrate design with manufacturing and increase efficiencies in new product development coordinated with manufacturing. Agile processes are key to the implementation and application success of such models. To a significant degree, the success of an Agile Manufacturing Unit or even the whole enterprise depends on the application of new technology which supports comprehensively accessing, exchanging, sharing and use information, and speeding up the information and work flow in the product development cycle.

Agile materials, capacity planning and control systems are a must. For this reason it is *unlikely* that over-sophisticated computer-based approaches will succeed over simple approaches. One of the mechanisms to achieve agility is the ability to provide forecasts throughout the supply chain of forthcoming demand without the buffering encountered in current supply chains. This is a significant challenge to the transparency of demand through the supply chain, without the intervention of inventory planners.

Agility requires not constant changes of plan to satisfy changing customer requirements, but very short lead-times. There is a switch of emphasis here from factory stability, to the customer need. This has a major impact also on production planning and control whereby a product is earmarked for a particular customer fairly early on in the process so that customisation may proceed from that point. This is opposed to the techniques of aggregation connected with MRP systems and is more akin to a make-to-order environment albeit that one product may be very similar to the preceding one.

An enabling factor in becoming an agile manufacturer has been the development of manufacturing support technology that allows the marketers, the designers and the production personnel to share a common database of parts and products, to share data on production capacities and problems — particularly where small initial problems may have larger *downstream* effects. It is a general proposition of manufacturing that the cost of correcting quality issues increases as the problem moves downstream, so that it is cheaper to correct quality problems at the earliest possible point in the process.

By using *simulation and optimisation models and techniques*, all those initial risks can be determined and managed more effectively. As part of our research, a further investigation will be taken into that particular area.

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