OVERCOMING THE TACIT KNOWLEDGE PROBLEM IN THE COMMERCIAL REFRIGERATION INDUSTRY USING MIXED-MODE MODELLING

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ABSTRACT

In this paper the common problem of remaining competitive in the face of considerable competition from overseas countries where labour and often materials are considerably cheaper, is considered. Remaining competitive is achieved through product differentiation i.e., customization. With customization comes the need for new product development. Unfortunately, industries such as commercial refrigeration exist where this process is far from straight forward since it suffers from missing knowledge and relies on tacit knowledge. The consequence of this overtly missing knowledge is that product development is more costly. This paper outlines the make-span problem for the refrigeration industry and suggests a mixed-mode modelling approach to minimize it.

INTRODUCTION

In some industries the production process is not able to be fully represented using a 'hard' model which contains known parameters together with a definitive mathematical model representing its operation. Some production processes that *appear* well defined and quantifiable are in *reality* at best 'guestimates', subject to complex sub-processes that determine their values. Under these circumstances, only models that approximate the process can be developed with the subsequent incorporation of the knowledge that factory floor workers or production operators hold in a tacit form. Examples of production involving tacit knowledge (hereinafter referred to as '*the tacit knowledge problem*') are found in the aluminium smelting industry (see[1]), float glass production and the refrigeration industry. The consequences of this tacit knowledge problem include greater product development costs and increases in product manufacture time (make-span). This is particularly true in the refrigeration industry where product development (and in the case the 'one-off' product) make-spans can be up to a year.

Polyani [2] is considered the authoritative source on tacit knowledge. Tacit knowledge is deemed very important since it is regarded by many ([3], [4]) as "fundamental to all human knowing and knowledge ([5 p60]). Tacit knowledge is popularly treated as personal or private knowledge and acquired through an individual's experience. There is also considerable discussion surrounding whether tacit knowledge can be actually converted into explicit knowledge (as required in this problem). However, the inability to articulate tacit knowledge in some situations is a real one and must be borne in mind (see [6], [7]). This paper aims to provide a *solution methodology* to substantially reduce the impact of the tacit knowledge problem in the commercial refrigeration industry where customisation (and therefore substantial product development) is critical to its existence.

THE MAKE-SPAN PROBLEM

Generally, as the level of customization increases, the new product development process requires greater cost and time. This applies more so for customization of products which suffer the tacit knowledge problem. In a generalized context, the production Phases involved in product development (and one-off products) in the commercial refrigeration industry are as follows:

(i) **Phase 1** - For Job i (J_i) contains the tasks k which take on average time $X_{i,k}$ ($k \in K_1$) that pertain to **initial** specifications, design and prototype construction. This Phase is only entered once.

(ii) **Phase 2 -** For Job i (J_i) contains the tasks k which take on average time $X_{i,k}$ ($k \in K_2$) that pertain to **subsequent** re-specifications, redesign and modifications to the prototype construction due to the previous product prototype not meeting technical and legal requirements due to the existence of the *tacit knowledge problem* (tkp). This phase is encountered in product development or one-off production of any product involving the tkp.

(iii) **Phase 3 -** For Job i (J_i) contains the tasks k which take on average time $X_{i,k}$ ($k \in K_3$) and are encountered *only in product development* (i.e., not 'one-off' products) irrespective of whether the tkp is present or not (although tasks in this Phase will potentially be encountered more often when the tkp is present). Tasks here include component re-sourcing, modifications to design etc.

(iv) **Phase 4 -** For Job i (J_i) contains the tasks k which take on average time $X_{i,k}$ ($k \in K_4$) and are encountered in all jobs irrespective of the existence or not of the tkp and whether the Job is product development or one-off production. Tasks include final product builds (from the prototype) and finishing and so on. This Phase is only entered once

The determination of the make-span of J_i (Z_i) is then:

$$Z_i = \sum_{k \in K_1} X_{i,k} + M \sum_{k \in K_2} X_{i,k} + N \sum_{k \in K_3} X_{i,k} + \sum_{k \in K_4} X_{i,k} \qquad (1)$$

iff the *tacit knowledge problem* is present and Job i is *product development;*

$$Z_i = \sum_{k \in K_1} X_{i,k} + M \sum_{k \in K_2} X_{i,k} + \sum_{k \in K_4} X_{i,k} \qquad (2)$$

iff the *tacit knowledge problem* is present and Job i is a *one-off;*

$$Z_i = \sum_{k \in K_1} X_{i,k} + N \sum_{k \in K_3} X_{i,k} + \sum_{k \in K_4} X_{i,k} \qquad (3)$$

iff the *tacit knowledge problem* is not present and Job i is *product development;*

$$Z_i = \sum_{k \in K_1} X_{i,k} + \sum_{k \in K_4} X_{i,k} \qquad (4)$$

iff the *tacit knowledge problem* is not present and the Job i is a *one-off;*

Note that N will be potentially much larger in (1) compared with (3). Also, $K = K_1 + K_2 + K_3 + K_4$.

In Phase 1, The tacit knowledge problem stems from the fact that there is no proven analytic technique that will give precise refrigeration designs that will exactly meet the infinite range of customer and regulatory requirements. The design referred to here relates to the positioning of cooling pipes, baffles,

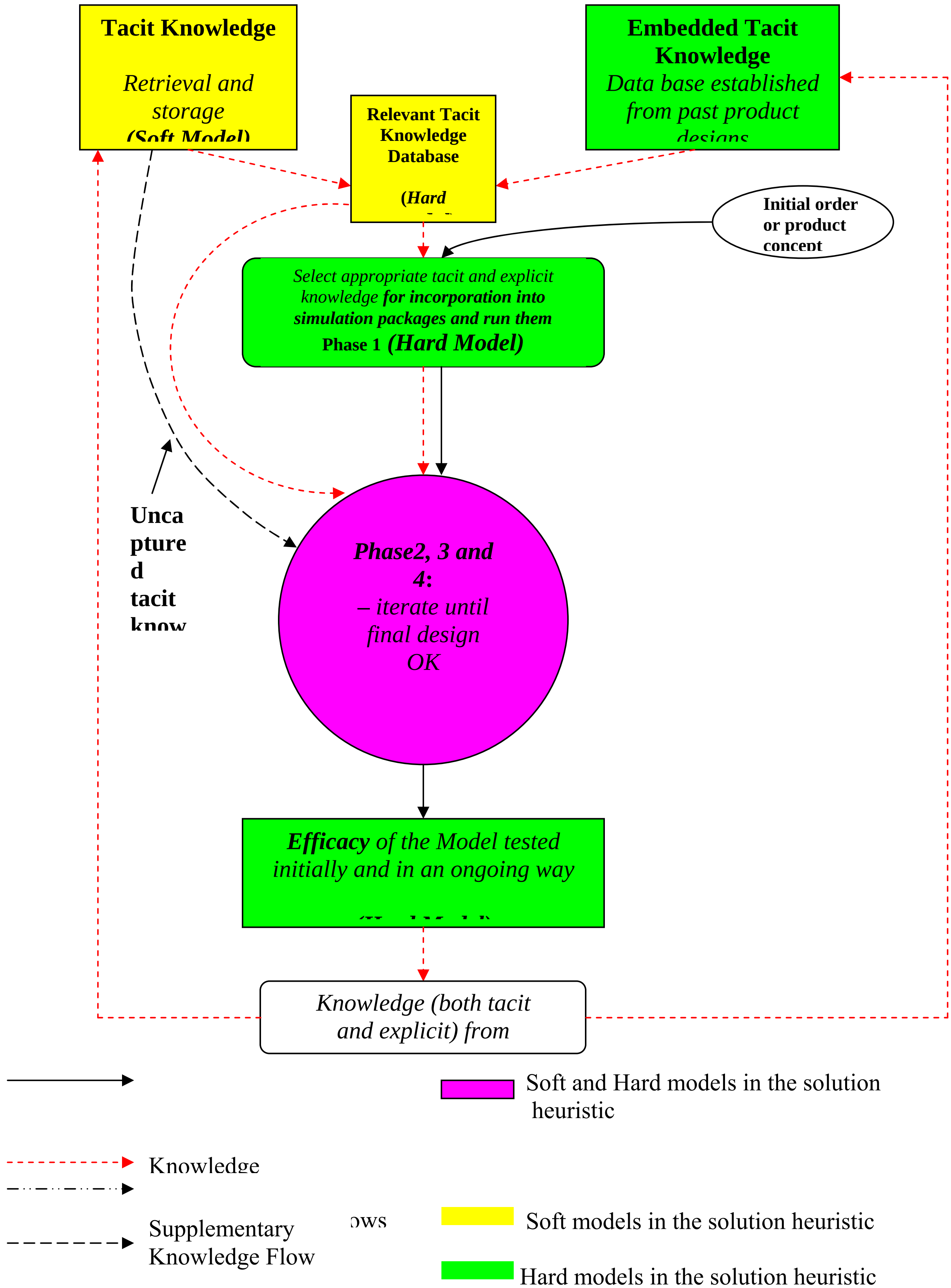

Figure 1. The Mixed-mode Modeling Solution Heuristic for a Refrigeration One-off Product or Product Development Job

air ducting etc within the cabinet of the refrigeration unit. Currently, the whole design and production process is an heuristic one that uses several simulation packages (initially) in conjunction with *ad hoc* adjustments performed by the refrigeration technicians (the application of tacit knowledge) and then ‘action’ testing and monitoring in refrigeration laboratories. If the design does not work, then the process can iterate (many times - up to twelve months in some cases).

THE HEURISTIC SOLUTION

There are a number of distinct stages in the *solution* of this problem (and hence in the *solution heuristic*) and it is based on that developed by [1]. The solution Stages are:

Stage 1 – Capture of tacit and embedded tacit knowledge (past and current) and their storage;
Stage 2 - The interrogation of the data bases of tacit knowledge to extract the information needed for the current job;
Stage 3 – The incorporation of this knowledge into the new product development (or one-off) job via input into the simulation packages and/or incorporation directly into the construction of the product prototype followed by the development of the prototype product and its subsequent testing and redesign where needed (see Figure 1). The fact that there will still be some tacit knowledge not captured and indeed new tacit knowledge generated, suggests that the input from the refrigeration technicians should continue to be sought in this stage also. This model is hard and soft.
Stage 4 – Testing the efficacy of the solution heuristic, initially through re-making old jobs and comparing the initial make-span with the new one arrived at using the solution heuristic. Additionally, for ongoing assessment of efficacy, a comparison of average make-spans for similar jobs before and after the implementation of the solution heuristic can be undertaken. The overall solution heuristic (incorporating the above Stages) is summarized in Figure 1 above.

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