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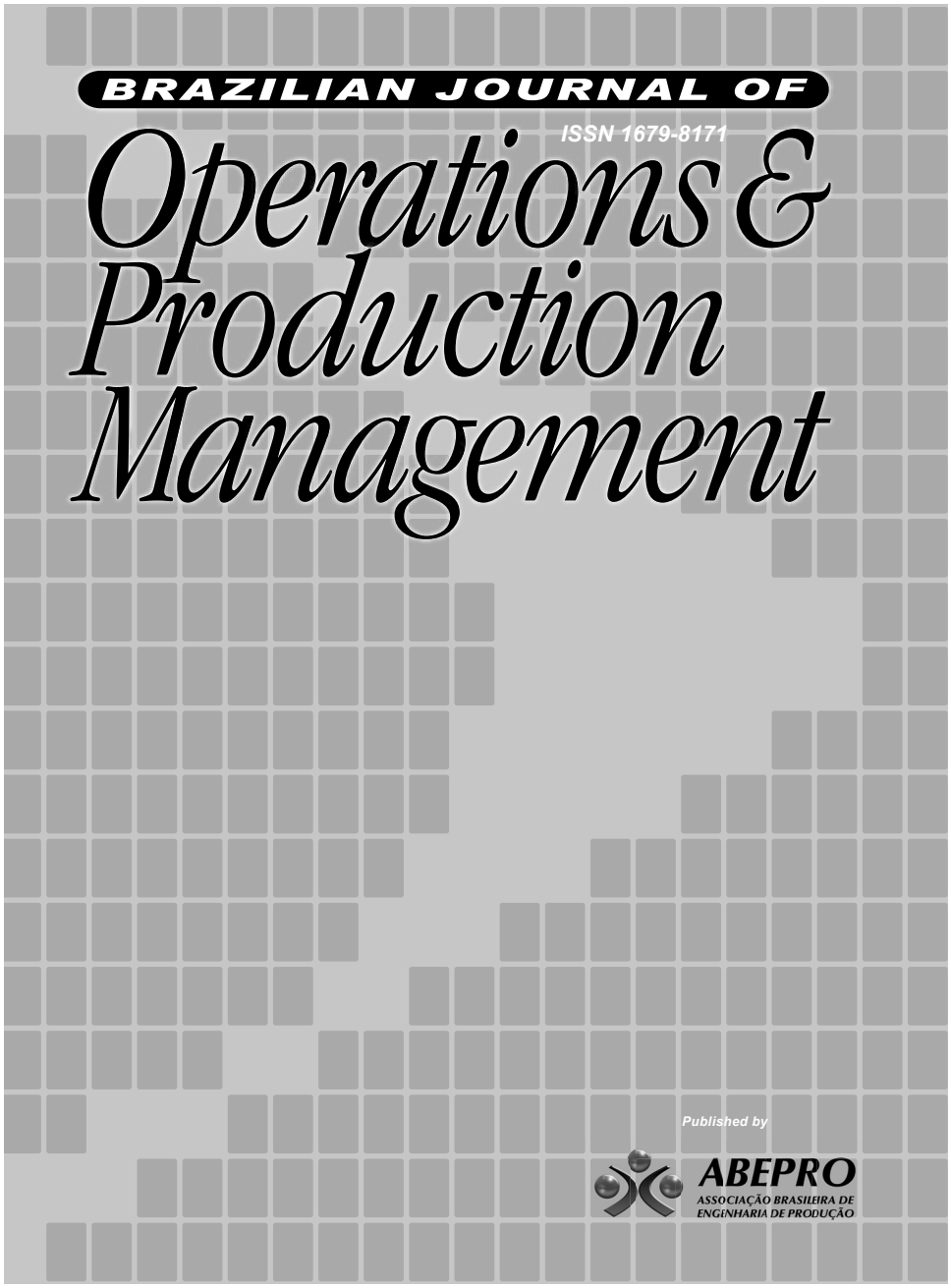

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Editorial Introduction

This is a special issue of the Brazilian Journal of Operations and Production Management that presents some of the best papers of the International Conference on Production Research - ICPR Americas 2006.

The third edition of the ICPR was held in Curitiba, Brazil, from 30th July to 2nd August, 2006. The general theme of the conference was Rethinking Operation Systems: New Roles of Technology, Strategy and Organization in Americas' Integration Era. The event was organized by the Brazilian Association of Production Engineering (ABEPRO), and the Industrial & Systems Engineering Graduate Program (PPGEPS) of the Pontifical Catholic University of Paraná (PUCPR). Besides these organizations, the event was also sponsored by the International Foundation for Production Research (IFPR), Federação da Indústrias do Estado do Paraná (FIEP), Universidade da Indústria (UNINDUS), Banco do Brasil, Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES), FESTO, HSBC, Revista PM, and Conselho Regional de Engenharia, Arquitetura e Agronomia do Paraná (CREA-PR).

About 200 papers were submitted coming from Americas and abroad. The conference received papers from Argentina, Canada, Chile, Colombia, Costa Rica, England, France, Germany, Japan, Mexico, Portugal, Russia, Turkey and United States. This confirmed the success and the growing prestige this event is getting among worldwide community.

A double-blind review process selected around 100 papers for oral presentations (allocated in 5 technical sessions) and 30 papers as posters. Among them, best ones were selected and the authors were invited to submit a more robust article. Then, these papers were double-blind reviewed and some of those that achieved the higher marks were selected to be part of this issue.

In this Issue

The subject of the first paper, by Martín G. Marchetta and Raymundo Q. Forradellas (National University of Cuyo, Argentina), is feature recognition to create a manufacturing process plan, in such a way that learning is embedded in plan libraries in order to achieve plan recognition. The second paper, by Luis E. Quezada, F. Córdova, P. Palominos (University of Santiago of Chile, Chile) and Christopher O´Brien (University of Nottingham, England), deals with performance measurement in manufacturing firms, proposing a model to formulate manufacturing strategies in small and medium companies. This paper is followed by the study of Carlos Montoya and Gonzalo Mejía (University of Los Andes, Colombia). It is dedicated to solve

workforce scheduling problems proposing a heuristic algorithm for this purpose. The subject of the fourth paper, by Sıtkı Gözlü and Aylin Coskun (Istanbul Technical University, Turkey), surveys eighty Turkish consultancy firms to define criteria of success in consulting operations. In the last paper of this issue, Eduardo Yamasaki Sato (University of Sussex, England), Dario Eduardo Amaral Dergint and Kazuo Hatakeyama (Federal Technological University of Paraná, Brazil), bring a study related to the dynamics of capabilities in an environment of technological change in the telecommunications industry.

We expect to have brought relevant issues as well as innovative approaches in the research of production/industrial engineering and operations management communities not only in the Americas but also from overseas.

We would like to thank ABEPRO Executive Board and the BJOPM Editorial Board for this opportunity.

This issue closes with ABEPRO's executive and ABEPRO's Editorial Board (NEA).

Sérgio E. Gouvêa da Costa, Ricardo M. Naveiro and Guilherme E. Vieira

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A New Model for Automatic Generation of Plan Libraries for Plan Recognition

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Abstract

In the context of Computer Aided Process Planning (CAPP), feature recognition as well as the generation of manufacturing process plans are very difficult problems. The selection of the best manufacturing process plan usually involves not only measurable factors, but also idiosyncrasies, preferences and the know-how of both the company and the manufacturing engineer. In this scenario, mixed-initiative techniques such as plan recognition, where both human users and intelligent agents interact proactively, are useful tools for improving engineer's productivity and quality of process plans. In order to be effective, these intelligent agents must learn autonomously this preferences and know-how. The problem of learning plan libraries for plan recognition has gained much importance in recent years, because of the dependence of the existing plan recognition techniques on them, and the difficulty of the problem. Even when there is considerable work related to the plan recognition process itself, less work has been done on the generation of such plan libraries. In this paper, we present some preliminary ideas for a new approach for acquiring hierarchical plan libraries automatically, based only on a few simple assumptions and with little given knowledge.

Keywords: Computer Aided Process Planning, Plan Recognition, Intelligent Agent, Plan Library Learning, Machine Learning, Planning

INTRODUCTION

The complexity of recognizing manufacturing features from a part design, along with the difficulty of generating a suitable (and in some sense good) manufacturing process

plan has largely been recognized. One of the problems of feature recognition is that of multiple interpretations of CAD designs in terms of manufacturing features. Since the resulting process plans depends on the feature model generated, multiple feature models (and also multiple process plans) must be considered.

Moreover, in addition to quantitative factors (such as cost and time), the selection of the best part interpretation in terms of features and the best process plan, often involves non-measurable factors, such as preferences, company's culture and know-how of the manufacturing engineers. This situation is reflected in the fact that in practice, engineers in the industry prefer the use of interactive tools rather than totally automated ones (Horváth and Rudas, 1993; Horváth and Rudas, 1994; Horváth and Rudas, 1995; Gao, 1999).

These are the main reasons why practical CAPP systems may increase their effectiveness by supporting mixed-initiative approaches. In these approaches, autonomous intelligent agents assist engineers proactively, but always considering the constraints that these users impose interactively. Thus, intelligent assistance is always guided by the (sometimes partial) decisions of the system users.

In order to allow this kind of proactive intelligence, the identification of the engineer's intentions must be performed while he is working. Once these intentions have been inferred, the intelligent agent may provide different kinds of aids, such as improvements proposals on the manufacturing process design, and the performance of tasks on behalf of the user. Plan recognition is a useful technique for identifying user's intentions.

Most existing techniques for plan recognition are based on the use of a plan library previously created (Kautz, 1987; Kautz, 1991; Lesh et al., 1999; Goldman et al., 1999). This library contains the different plans the user may pursue when using the application (within this work, the application is a CAPP system). There are different representations for plans, but all of them basically represent a set of actions that must be performed, along with a set of constraints on their execution.

Until some years ago, these plan libraries were hand coded by a human expert, which is difficult, tedious, and it makes difficult to port plan recognition systems to new domains (for example to different industries).

In recent years, the automatic and semi-automatic generation of plan libraries has gained much importance, because of the reasons mentioned above. Some approaches, with different results, have been developed.

A known way for acquiring plan libraries automatically is to generate all possible goals and plans for a given domain, possibly using some bias to allow only valid goals and plans (Lesh et al., 1999; Lesh, 1998).

On the other hand, some works present an approach based on the acquisition of plan libraries from example cases. The generation of such libraries by this method can be achieved in several ways. One of them is to use some abstraction method to produce a non-hierarchical, subsuming plan for a set of action sequences that achieves a known goal,

using labeled examples and some knowledge about an abstraction hierarchy of concepts (Bauer, 1998a; Bauer, 1998b). In (Bauer 1999a), a clustering approach is presented, that eliminates the need of goal annotation for examples. In (Bauer 1999b), a similar algorithm is presented, but the approach here is to group similar action sequences that belong to a known goal, thus generating alternative decompositions for that goal.

Another approach is to generate hierarchical decompositions of goals and composed actions, from labeled example cases (Garland et al., 2000; Garland et al., 2001).

In addition to the difficulty of porting plan recognition systems to new domains, an important reason for automating the generation of plan libraries is autonomy. The works mentioned above automate some of the tasks that are needed to build plan libraries. However, all of them require some human expert intervention in order to work. This is an important problem since the intelligent agents supporting manufacturing process planning should learn the company's know-how, and improve their own performance with experience.

As far as we know, the automatic acquisition of hierarchical plan libraries, from unlabeled example cases (that is, unsupervised learning of plan libraries), has not been achieved yet. In this paper, we present some ideas for acquiring such libraries, with little hand coded knowledge and unlabeled example cases. An example from the flexible packaging domain, as described in (Ibañez et al., 2003) and (Ibañez et al., 2001), is given to illustrate the algorithm.

PLAN LIBRARIES GENERATION ISSUES

There exist many representations for plan libraries, which contain different kinds of information. The algorithm presented in this paper is focused on the specific aspect of inferring plan decompositions from unlabeled action sequences.

A decomposition of an action is a set of simpler actions that have to be performed in order to accomplish it. A composed action can have several alternative decompositions, and each decomposition can be made up of either other composed actions or other basic ones (see Kautz, 1987; Kautz, 1991).

In order to learn such decompositions, an automatic segmentation mechanism must be provided. Such a mechanism must have the capability of identifying higher-level actions, by grouping the primitive ones that are observed from the user's interaction with the application, detecting recurrent patterns.

One difficult problem that arises, is that of interleaved plans. Previous works assume that each action sequence observed, contains only actions related to one goal (Bauer, 1998a; Bauer, 1998b), or that there may be actions for more than one goal, but the segmentation is not inferred, but given by the trainer, by means of labeled examples (Garland et al., 2000; Garland et al., 2001). This could be true if the observations (action sequences), are provided by an expert, or by somebody who is explicitly training the

system. However it would be useful to use an algorithm that can operate even with interleaved plans and unlabeled examples, in such a way that the agent can learn autonomously while the engineer uses the system.

GENERATION OF PLAN LIBRARIES

The model used for plans representation in this work is similar to that described in (Kautz, 1987) and (Kautz, 1991). Under this representation, a plan library is a graph containing actions (also called events) as its nodes. In this work, we use terms "action" and "event" as synonyms. Actions are connected by 2 kinds of edges: thick grey arrows represent "is a" relations and thin black arrows represent "part of" relations. A special action called End Event, has a "is a" relation with all the "top-level" actions (actions that are not part of another one, and that are performed for their own purpose). A plan library defined in this way is a structure that represents the hierarchy of actions that are relevant to a domain.

Before introducing the segmentation algorithm, we present some assumptions. First, we assume that each action sequence is complete, that is, it contains at least all the actions necessary to achieve every goal present on it. For example, if the action sequence AS_1 contains actions for two interleaved plans P_1 and P_2, then at least it contains all the actions needed for achieving the goals of P_1 and P_2.

Second, if two different plans appear always together in the observations, then they may be considered as the same one. The third assumption is that, if two composed actions share some basic ones, the hierarchy generated may not be exactly the real one, but an equivalent hierarchy, as will be shown in following sections. These two facts are assumed since the final aim of this work is to produce a system whose behavior is as much faithful as possible with respect of the user's behavior, even when the internal plan library is not an exact representation of the reality.

Finally, we assume that information of pre-conditions and effects of the primitive actions that can be observed is available (information for planning).

Decompositions

The first problem that must be solved is to infer segmentation of actions. Segmentation can be defined as the grouping of sets of actions that must be performed, for achieving a more general one. Thus, the segmentation is the result of the identification of decompositions of non-primitive actions. A desirable property of a segmentation algorithm is it being incremental, so the previously made inferences are used in subsequent steps, instead of storing the processed example cases.

Intuitively, whenever a set of new actions appears in an action sequence, this set of actions can be considered as a decomposition for some new (and previously unknown)

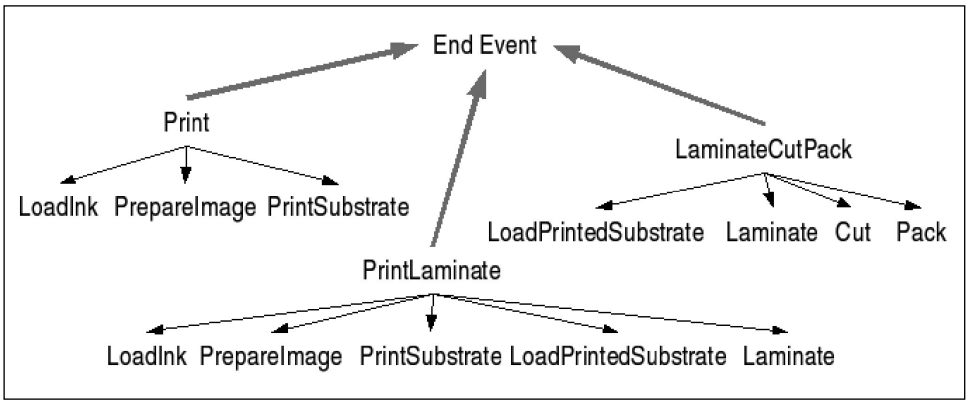

Figure 1: Simple plan library for packaging industry domain

non-primitive one that represents the observation. For example, consider the simple plan library presented in figure 1, which represents a simple plan library within the flexible packaging domain (see Ibañez et al., 2003).

Initially the system has an empty library that contains only the End Event. Now suppose that the agent perceives the following action sequence included by the user into a process plan during a session in the system:

$$AS_1 = \{\text{LoadInk, PrepareImage, PrintSubstrate}\}$$

Because none of the actions have been seen before, the agent creates a new composed action, named Print' whose parts are LoadInk, PrepareImage and PrintSubstrate (we denote the learned composed action with an apostrophe to show that the system will assign an arbitrary name to it).

A different situation arises when the agent observes an action sequence that contains parts of both known and unknown non-primitive actions. In this case, these actions can

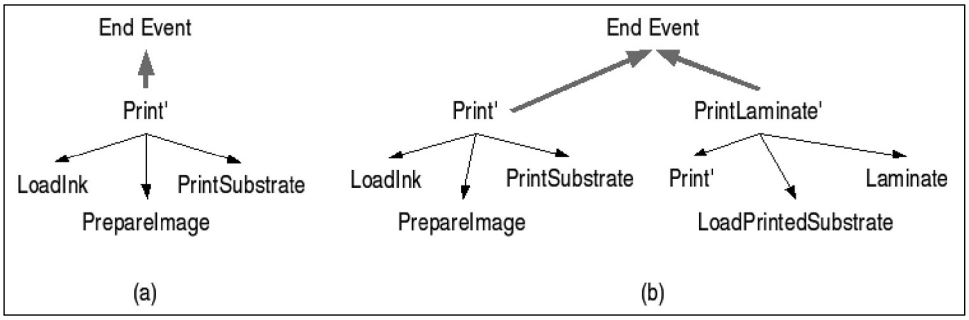

Figure 2: Plan library under construction

be considered as the parts of a more general event that represents the entire sequence. For example, suppose that the user includes the following actions in the process plan:

$$AS_2 = \{LoadInk, PrepareImage, PrintSubstrate, LoadPrintedSubstrate, Laminate\}$$

Here, LoadInk, PrepareImage and PrintSubstrate are identified as a decomposition of Print', so the algorithm will create a new composed action named PrintLaminate', which has Print', LoadPrintedSubstrate and Laminate as its parts. In figures 2.a and 2.b, the states of the plan library after the first and second observation, are shown.

Now suppose that the action sequences were seen in the inverse order. After the first sequence, the agent introduces in the plan library the action PrintLaminate', with LoadInk, PrepareImage, PrintSubstrate, LoadPrintedSubstrate and Laminate as its parts. When the second sequence is processed, only a part of a known action is identified. In these cases, the agent must figure out that, in fact, LoadInk, PrepareImage and PrintSubstrate are part of Print', which in turn is part of PrintLaminate'.

Thus, the action taken by the agent should be to create Print', and modify PrintLaminate' as needed. Finally, the new action is added to the plan library, in accordance with the segmentation, obtaining as before the state shown in figure 2.b.

Definition 1 (Complete decomposition).
A set of actions AS containing all of the parts of a composed action A_c,
is a complete decomposition of A_c.

Definition 2 (Partial decomposition).
A set of actions AS containing some parts of A_c, but not all of them,
is a partial decomposition of A_c.

The base of the method intuitively described before, is the identification of unknown actions, complete decompositions and partial decompositions. In absence of further information, all new action sequences are considered as part of a new non-primitive action. With the arrival of new example cases, the plan library is refined successively. These refinements are based on the complete and partial decompositions identified in the new observations.

A schematic algorithm for generating hierarchical decompositions for plan libraries, named HIDEL (HIerarchical DEcomposition Learner), is shown in Figure 3. This algorithm handles several cases that can arise, related to a new action sequence:

a. It has no previously seen basic actions.
b. It includes only complete decompositions of already known composed actions.
c. It presents some basic actions that have not been seen, and some actions that are a complete decomposition of already known actions.
d. It contains a partial decomposition of known actions.

```
HIDEL(AS , PLibrary)
Variables:
  AS: A new action sequence
  PLibrary: The current plan library
BEGIN
  CompDec = IDENTIFYCOMPLETEDECOMPOSITIONS(AS)
  PartDec = IDENTIFYPARTIALDECOMPOSITIONS(AS)
  Unknown = IDENTIFYUNKNOWNACTIONS(AS)

  NewSeq = CREATEACTIONSEQUENCE()
  for each decomposition in CompDec
     add composed action corresponding to decomposition to NewSeq

  add actions( Unknown) to parts(NewSeq)

  for each decomposition in PartDec
     NewAction = CREATEACTION()
     add actions(decomposition) to parts(NewAction)
     add NewAction to NewSeq
     replace actions(decomposition) with NewAction in PLibrary

  if empty(IDENTIFYCOMPLETEDECOMPOSITIONS (NewSeq))
     if elementCount(NewSeq) > 1
        NewAction = CREATEACTION ()
        add actions(NewSeq) to parts(NewAction)
        add NewAction to Plibrary as End Event
  else
     NewAction = getAction(1,NewSeq)
     If not(isSpecialization(End Event, NewAction))
        add NewAction to PLibrary as End Event
END HIDEL
```

Figure 3: Schematic segmentation algorithm

In case (a), the system can segment all the actions as part of a new composed event. In case (b), known non-primitive actions are identified from the sequence. Two situations may arise for this case. If the identified non-primitive actions constitute a complete

decomposition, then the plan library already contains the information implied by the observation. For example, if the current state of the plan library is that of figure 2.b, the sequence

AS = {LoadInk, PrepareImage, PrintSubstrate,LoadPrintedSubstrate,Laminate}

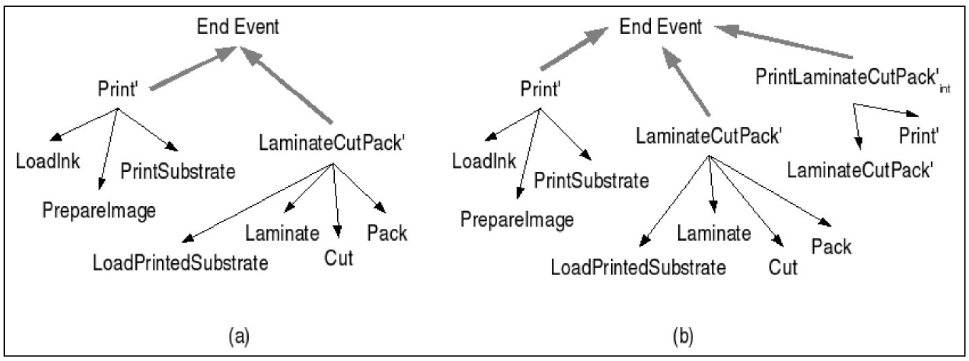

Figure 4: Plan library learned in case (b)

represents PrintLaminate', so no change is needed for the plan library.

On the other hand, if the identified composed actions are not a complete decomposition, they are arranged as parts of a new action. Consider figure 4.a. After the sequence

AS = {LoadInk, PrepareImage, PrintSubstrate,LoadPrintedSubstrate,Laminate, Cut, Pack}

is observed, all the actions included in the observation are part of known composed actions Print' and LaminateCutPack'). However, LaminateCutPack' and Print' are not a complete decomposition, so the system creates a new composed action $\text{PrintLaminateCutPack}'_{int}$, with them as its parts. The results of the segmentation are depicted in figure 4.b. The action $\text{PrintLaminateCutPack}'_{int}$ could either be a real plan (or subplan), or two interleaved plans (as in the example). Interleaved plans will be described in following sections.
In case (c) the algorithm builds a new composed event, whose parts are the unknown actions in the sequence and the composed actions identified from the known primitive ones observed. An example of this situation is the first one presented intuitively, where the following sequences were processed (see figure 2).

AS_1 = {LoadInk, PrepareImage, PrintSubstrate}
AS_2 = {LoadInk, PrepareImage, PrintSubstrate,LoadPrintedSubstrate,Laminate}

Finally, when the new observation contains a partial decomposition, as in case (d), it is likely that these actions are in fact parts of a composed event, which in turn is shared by the previously known one, and a new one that must be created. An example of this case, is the same as the previous one, with the observations in the inverse order:

AS_1 = {LoadInk, PrepareImage, PrintSubstrate,LoadPrintedSubstrate,Laminate}
AS_2 = {LoadInk, PrepareImage, PrintSubstrate}

Figure 5.a shows the state of the plan library after AS_1, and figure 5.b shows the state after AS_2. Here, actions LoadInk, PrepareImage and PrintSubstrate are grouped as part of Print', which is the new composed action created in accordance with the new observation, and PrintLaminate' is modified as needed.

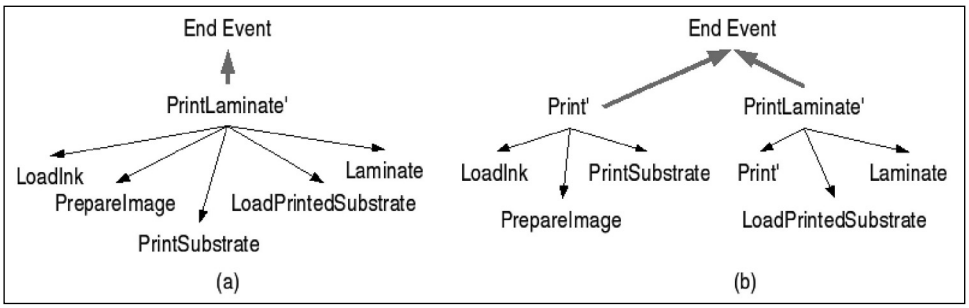

Figure 5: Plan library learned in case (d)

Interleaved plans

When an action sequence contains actions of more than one plan, some special problems arise. Interleaved plans generate difficulties because in absence of further information, a plan library learning algorithm cannot distinguish between interleaved plans, and an individual composed plan. Consider again the plan library shown in figure 1. Suppose that the action sequence

AS_1 = {LoadInk, PrepareImage, PrintSubstrate,LoadPrintedSubstrate,Laminate, Cut, Pack}

is observed. Without additional information, it is difficult to infer if the whole observation corresponds to a single plan, or if it corresponds to two interleaved plans (Print and LaminateCutPack), so the system creates InterleavedPlans' to represent AS_1.

If the sequence

$$AS_2 = \{\text{LoadInk, PrepareImage, PrintSubstrate}\}$$

is processed, a new action is created whose parts are LoadInk, PrepareImage and PrintSubstrate, and InterleavedPlans' is updated. As can be seen, the new observation did not solve the problem.

We propose two alternatives to address this problem, depending on the bias imposed to the plan library representation. In (Kautz, 1987), an event can be a part of another one, or can be an End Event, but not both at the same time. If this bias is imposed to the representation of plan libraries, when an action that is part of a more general one appears alone in a new observation, as an end event (i.e, it appears as executed for its own sake), it follows immediately that the previously inferred composed action was, in fact, an interleaving of more than one plan. In the above example, when AS_2 is processed the composed action Print' is created, and because it appears as executed for its own sake, it follows that InterleavedPlans' contained, at least, two interleaved plans (Print' and the rest of InterleavedPlans'), so a reasonable modification to the plan library would be to remove actions of Print' from InterleavedPlans'.

However, in some domains it could be useful to allow an action to be a part of another one, and a top-level action at the same time (see Goldman et al., 1999). For these cases, another mechanism is required in order to avoid the ambiguity of interleaved plans. One feasible technique for this, is the use of a probabilistic rule. In (Marchetta and Forradellas, 2006), an algorithm was presented that follows this approach.

The solution proposed in that work is to compute the probability that some action A' is in fact the interleaving of several plans, instead of a real composed one. Let $N(A'_T)$ be the number of action sequences observed by the agent, in which either A' or any of its compounding parts appear. Then

$$N(A'_T) = N(A'_{\text{int}}) + N(A'_{\neg\text{int}}) \qquad [1]$$

where $N(A'_{\text{int}})$ is the number of action sequences where A' appears as an interleaved plan, and $N(A'_{\text{-int}})$ is the number of sequences where it appears as a real plan.

Since the agent cannot directly determine whether A′ or not an interleaved plan, the actual value of $N(A'_{-int})$ is approximated as the number of sequences where any of the parts of A′ appear as end events.

Thus, the probability of A′ being an interleaved plan is computed as follows

$$P(A'_{\text{int}}) = \frac{N(A'_{\text{int}})}{N(A'_T)} = \frac{N(A'_{1e}) + N(A'_{2e}) + \cdots + N(A'_{ne})}{N(A'_T)} = \qquad [2]$$
$$= P(A'_{1e}) + P(A'_{2e}) + \cdots + P(A'_{ne})$$

where $N(A'_{ie})$ is the number of sequences where the i-th part of A′ appears as an end event.

This probability can be used in two ways:

1. Comparing it with the probability that the action is real
2. Using a threshold, beyond which the action can be considered as an interleaving of plans

Shared steps

At first sight, the fact that two composed actions share some steps should not be a problem. However, there exist some situations in which the algorithm shown in figure 3 generates an incorrect plan library.

Consider again the plan library shown in figure 1. Suppose that the sequences

AS_1 = {LoadInk, PrepareImage, PrintSubstrate}
AS_2 = {LoadInk, PrepareImage, PrintSubstrate,LoadPrintedSubstrate,Laminate}
AS_3 = {LoadInk, PrepareImage, PrintSubstrate,LoadPrintedSubstrate,Laminate, Cut, Pack}

are processed. In figure 6, the plan library state after the processing of each sequence according to the schematic segmentation algorithm is shown.

In the example, InterleavedPlans′ represents the interleaving of the events PrintLaminate and LaminateCutPack. If the learning mechanism can handle interleaved plans (for example, using some of the approaches mentioned in the previous section), as new example cases are processed PrintLaminate′ will be eventually removed from InterleavedPlans′. This last modification should turn InterleavedPlans′ into a representation of LaminateCutPack′, but instead it results in a new action whose parts

are Cut and Pack, and which is not a real or significative one. Thus, the resulting plan library definition is not equal (or even equivalent) to that presented in figure 1
This problem arises when the following conditions hold:

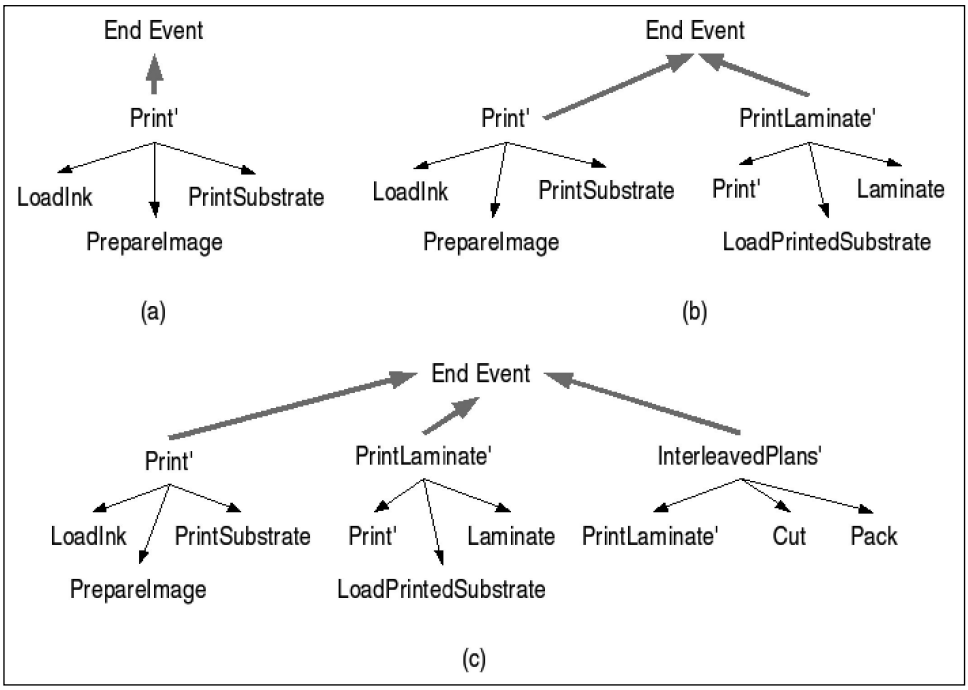

Figure 6: Plan library evolution for shared steps

1. Two composed actions shares some common parts
2. The composition of one of them is already known from previous observations
3. The other action appears later in an observation

Some modification could be made to the segmentation algorithm in order to avoid this situation, but we think that the most feasible solution is to define some mechanism to revise the definition of actions that could potentially share common steps, as new evidence is processed.

The algorithm presented in (Marchetta and Forradellas, 2006) for handling interleaved plans, which was briefly shown in the previous section, may solve this problem. In the proposed mechanism, with each new action sequence perceived by the intelligent agent, it computes for each non-primitive action of the plan library the probability that it is a real plan or an interleaving of two of them. When this probability reaches some threshold, the corresponding non-primitive action is removed from the plan library.

Since the problem presented in this section may lead to the introduction of some

spurious non-primitive actions in the plan library, which will not appear systematically, the same mechanism may be used to remove them, and also to remove other kind of spurious actions from the plan library.

Alternative decompositions

Alternative decompositions of a non-primitive action, are the different ways in which it can be accomplished. Recall that a composed action is one that is accomplished when all its parts are performed. This type of actions may be accomplished in different ways. Within the decomposition of an action, its parts have an implicit conjunction relationship. Alternative decompositions, instead, have a disjunction relationship with each other within a composed action.

The conjunction of the effects of primitive actions that are part of some decomposition, can be seen as the goals that are achieved by that decomposition. If two actions sets are alternative decompositions of a composed action, then they both achieve the goal of the composed action. Thus, if two decompositions have the same conjunction of effects, then they can be considered as alternative decompositions of the same action.

Since we assume that information about the pre-conditions and effects of primitive actions is available as domain knowledge, alternative decompositions of actions as well as the goals of composed actions inferred, can be determined.

CONCLUSIONS AND FUTURE WORK

An algorithm for learning hierarchical plan libraries for plan recognition from unlabeled example cases was presented in this paper. Some complementary ideas for supporting interleaved plans and alternative decompositions were also introduced.

One of the long term objectives of this work, is to produce new techniques that allow a plan recognition system (part of an intelligent agent) to adapt automatically to new domains, assuming that known and new domains are modeled by the same basic actions (the actions used by the agent for planning), thus providing a high autonomy level to the agent using these techniques. In the CAPP domain, different companies may have the same manufacturing resources, but also have different preferences, policies and strategic objectives, which yield different manufacturing process plans. An intelligent agent with learning capabilities within a mixed-initiative environment may adapt itself to these differences.

Even when the ideas presented in this paper are promising, future work must include further development, in addition to an implementation and validation of the algorithms with real data from the CAPP domain within different industries. Some additional features must also be taken into account: abstractions of actions ("is a" relations), the inferring of actions orderings, actions with parameters, the inferring of restrictions on these parameters, and support of repeated and spurious actions.

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Conceptual Model for the Generation of Performance Measures in Manufacturing Firms

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Abstract

This paper shows a conceptual model for the generation of performance measures in manufacturing firms. The conceptual model is based on a hierarchical approach for formulating manufacturing strategies in small and medium enterprises, which structures the process as a hierarchy and links the levels using tools of the Analytic Hierarchy Process (AHP). The original model consists of 4 levels: (a) the well-being of the company, (b) strategic objectives, (c) strategic business units, (c) critical success factors and (d) manufacturing decision area. This model includes the four perspectives of the Balanced Scorecard, as follows. The financial perspective is included in the strategic objectives, the customer perspective is included in the critical success factors and the process perspective and innovation & development perspective are included in the manufacturing decision areas. In this way, the same hierarchical model for formulating a manufacturing strategy can be used as a tool for generating performance measures. The main contribution of this work is that it provides with a systematic mechanism for generating performance measures. It also allows the assignation of weights to the measures created, using a well known and proved process as AHP.

Keywords: Performance measurement, Balanced Scorecard, manufacturing strategy, analytic hierarchy process.

INTRODUTION

Manufacturing strategy has been a concept and an area of study since the early work by Skinner (1969). However, the large of approaches that have been described in the literature has created some confusion regarding the way the strategy is formulating. This article refers to the way the manufacturing strategy is formulated and the way performance measures are defined in order to evaluate the strategy and the operation of the company. The formulation of a manufacturing strategy is a process, by which the company establishes their long term objectives of the manufacturing function, defines action plans and allocates resources to achieve those objectives (Wheelwright, 1978).

Taken the structure of the hierarchical model of a manufacturing strategy proposed by Quezada et al. (2003) is possible to identify the four perspectives of the Balanced Scorecard developed by Kaplan and Norton (1990) to produce performance measures at a strategic level. The perspectives are Financial, Clients, Internal Processes and Learning & Development. This latest perspective can be incorporated from the contribution of Platts and Maslem (1997), who argue that, apart from the traditional manufacturing decision areas of structure and infrastructure, the management of human resources should be considered separately of the others. Give this comparison as a starting point; it is possible the generation of performance measures to control the organization under the dynamic scenario that the environment presents.

This work aims at developing a methodology to generate and select performance measures for the manufacturing area. The proposed methodology is a combination of the model for formulating manufacturing strategies proposed by Quezada et al. (2003) and the Balanced Scorecard proposed by Kaplan and Norton (1990). The methodology attempts to fill the gap between the theory and the practice in the area.

PERFORMANCE MEASUREMENT IN MANUFACTURING

The subject of performance measurement has attracted a lot of attention recently in the business and manufacturing literature, even it if is not new. Neely (1999) states that between 1994 and 1996 some 3,615 articles were published. He states that performance measurement is still on the management agenda. He also argues that there are four basic questions that research in business performance seeks to address: (1) What are the determinants of business performance?, (2) How can business performance be measured?, (3) How to decide which performance measures to adopt? and (4) How can the performance measurement system be managed?.

As cited by Neely et al. (1995) "when you can measure what you are speaking about, and express it in numbers, you know something about it… (Lord Kelvin,1824-1907)". They also state that "Performance measurement is a topic which is often discussed but rarely defined" They analyze performance measures related to cost, quality, flexibility and time. However, the purpose of this literature review is not actually to present specific

measures of performance, but to give some guides to the process of designing a measurement system. What is surprising is that for managers it is easy to decide what should be measured. What is difficult for them is to reduce the number of measures to a set that is manageable and useful. It is very easy to decide which measures of performance to use, but this does not means that they are the right measures. One relevant aspect for this project is that these authors emphasize the need to do more research in the case of small of small and medium sized companies, where performance measurement system are considered as a luxury. A large number of studies, such as those undertaken by Blenkinsop and Burns (1992), Dummond (1994) and Evans (2004) attempt to relate external and internal variables with the management control system, but they do not study the generation of performance indices in manufacturing.

In the same way, Gomes et al. (2004) make a very good literature review of manufacturing performance measures and measurement. They reviewed 388 articles from relevant journals, 144 papers from conference proceedings and some relevant books. They considered the literature published from 1988 to the end of 2000. They make an historical analysis, presenting some criticisms to the early approaches and the performance measurement systems that have been developed in response to those criticisms. They point that among those systems, the Balanced Scorecard is the most cited, even though it has also been criticized. In their study its is possible to observe the evolution of performance measures and measurement, going from individual measures considering a company as a close system to performance measurement systems that look at the company in an holistic way.

Melnyck et al. (2004) argue that in spite of the importance of the performance measurement little research has been undertaken in the area of operations management. In the same way, they state that performance measurement continues being a challenge both for managers and researchers.

A different literature survey was developed earlier by White (1996), who attempts to produce taxonomy of strategy-related performance measures for manufacturing. He emphasizes that in most of the cases the performance measures are orientated to the achievement of "competitive priorities", such as cost, quality, flexibility and delivery. The taxonomy classifies the 125 indicators into the following types: competitive capability, data source, data type, reference and orientation. After the analysis, the author concludes that performance measures is a topic of considerable current interest both practitioners and academics, but the field remains unstructured, with no framework for evaluating performance measures.

Finally, Neely (2006) in his analysis of the literature also stresses the dominance of the balanced scorecard. However, he points out that the research community must take the research agenda forward in order not to be trapped by solutions proposed for problems of the past.

THE METHODOLOGY FOR FORMULATING A MANUFACTURING STRATEGY USING AHP

The methodology for formulating manufacturing strategies presented here was developed by Quezada et al. (2004). It is orientated to MSEs and it is based on a quantitative approach and takes advantage of the hierarchical structure of the traditional conceptual model for manufacturing strategies.

It uses some concepts of strategic planning, which are the following:

Strategic Business Unit (SBU). It is an organizational unit which can be managed more or less independently from other units. To operasionalize the concept, the definition given by Widmer (1997) is used, which establishes that a SBU is a pair Product-Market Segment with homogeneous characteristics.

Critical Success Factors (CSF). They correspond to those characteristics of a good or services that are considered by the customer to make the decision of selecting the vendor. Hill (1985) calls them Order Winning Criteria.

The methodology represents the process in a hierarchical way:

Level 0: This level corresponds to the welfare of the company.

Level 1: This level includes the long term objectives of the firm.

Level 2: This level corresponds to the Strategic Business Units of the firm.

Level 3: This level corresponds to the Critical Success Factors of each SBU.

Level 4: This level represents the manufacturing decision areas.

The manufacturing decision areas are: facilities, capacity, process & technology, scope of process, quality management, control systems, human resources management, supplier's management and product design. They were taken directly from the literature (see for example, Wheelwrigth (1978), Schroeder (1990), Hill (1985) and Platts (1990)). For the purpose of this work, they are classified into two main areas: structural and infrastructural. The first main area includes the first four manufacturing decision areas and the second main area includes the rest of them, with the exception of human resources management, which is treated independently, as proposed by Platts and Maslem (1997).

The levels are connected using the tools of the Analytic Hierarchy Process (AHP), developed by Saaty (1996a). This approach assigns weights to every node of each level. In this way, a weight is given to each manufacturing decision area, representing their importance in supporting the objectives of the company. As it can be read in Quezada et al. (2003), this model represents the basis for generating manufacturing strategies and action plans. A simplified version of the hierarchical model is depicted

in Figure 1.

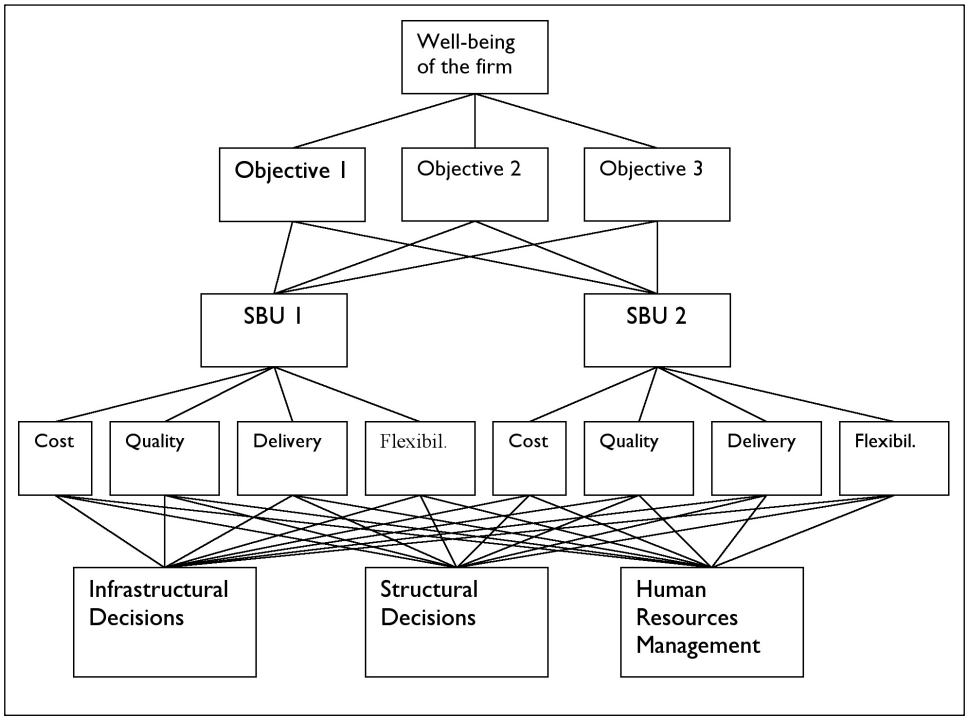

Figure 1: Hierarchical Model for Manufacturing Strategy (Adapted from Quezada et al. (2003).

GENERATION OF PERFORMANCE MEASURES

From the work carried out by Kaplan and Norton (1990), an organization can be seen from four perspectives: Finances, Customers, Internal Processes and Innovation & Learning.

Performance measures are defined for each perspective, specifying the objective pursued their targets, the strategic initiatives to achieve the objectives and the actual results obtained. It is important to point out that the objectives must be related to the vision, mission and strategies of the firm.

At this point, the methodology proposed by Quezada et al. (2003) for formulating manufacturing strategies and the perspectives of the Balanced Scorecard approach are analyzed to try to establish a formal relationship between them. A relationship is formalized in order to define performance measures in manufacturing.

Financial Perspective: What do the shareholder expect from the firm?

The financial results are considered to be a result of the actions developed by the company. In this way, the Balanced Scorecard establishes that the financial situation of a company is no more than the results of the actions taken in the other perspectives.

The financial perspective is directly related to the objectives of the company or the scale of value of the owner(s) or directory. In other words, the financial perspective is related to the Level 1 of the hierarchy presented in Figure 1. The objectives established in Level 1 will serve as a basis for the decisions to be made in the other perspectives. The hierarchical model is wider in the sense that not only the financial criteria are considered, but the scale of values as well.

Customer Perspective: What aspects of the relationship with customers do determine the financial results?

In order to achieve the financial performance desired by the company, it is fundamental to have satisfied and loyal clients. With this objective in mind, the relationship with clients and the expectations they have about the company are measured.

This perspective takes into account the main elements that generate value to the clients, in order to focus the company only on key processes. The main elements of the product or service make the customer select the company and order them. According to these characteristics, this perspective is related to the Level 3 of the hierarchy, which includes the critical success factors of each SBU.

Internal Processes Perspective: What are the internal processes in which we must be outstanding to satisfy our customers?

Taken into account the marker the objectives of the company and the market(s) in which the company is participation, the key internal processes of the organization are identified. It is important to orientate the efforts to achieve the excellence of the product and services required by customers, keeping in mind the vision of the company.

The internal processes perspective is related to the manufacturing decision areas (Level 4 of the hierarchy), because it includes all the manufacturing processes (structural and infrastructural). The structural processes include those related with the actual manufacturing process, while the infrastructural processes include those related to management elements.

Innovation & Learning Perspective: What do we have to do to develop the human resources to achieve the excellence in our key processes and to achieve the vision?

This perspective is the driver of all the previous perspectives of the balances Scorecard and it reveals the knowledge and capabilities that the company has to develop the products and services, as well as for changing and learning.

To establish a relationship of this perspective with the hierarchy of the manufacturing strategy, the extension of the manufacturing areas proposed by Maslen and Platts (1997) is used. The human resources management decision area is set at the same level of the structural and infrastructural manufacturing decision areas (as shown in Figure 1). This area considers all aspects of human resources, such as culture, competences

and training, which are related directly to the growth and learning of the organization. Therefore, the manufacturing decision areas of Structure and Infrastructure are related to the Internal Processes Perspective and the Human Resources Management is related to Innovation & Learning Perspective.

Then, the Level 4 that corresponds to the manufacturing decision areas can be divided into the following categories:

Table 2: Manufacturing decision areas for the creation of capabilities (level 4)

Structure	Infrastructure	Human Resources
Facilities Capacity Process & technology Scope of process	Quality management Control systems Suppliers management Design	Culture Organization Competences Training Rewards and incentives Communication

After having established a relationship between the perspectives of the Balanced Scorecard and the hierarchical model for formulation of manufacturing strategies, it is possible to present the conceptual model for the generation of performance measures in manufacturing.(Figure 2, on next page)

It is important to note one difference between the model hierarchical model of Figure 1 and the conceptual model of Figure 2. In the first case, the area of human resources management is in the same level of the manufacturing areas, but it the last case; it is located in a lower level. This is because it was intended to be consistent with the BSC approach, in which the human resources are part of the learning perspective, which is the lower one. It is also mentioned that the directions of the arrows in Figure 2 are related to the hierarchical process, in which they have a meaning of dependence, which is different from the case of the BSC where they represent influence.

The process for creating the manufacturing performance measures is:

1. Formulation of a Corporate/Business Strategy
   - Definition of Mission and Vision.
   - Identification of Long Term Objectives

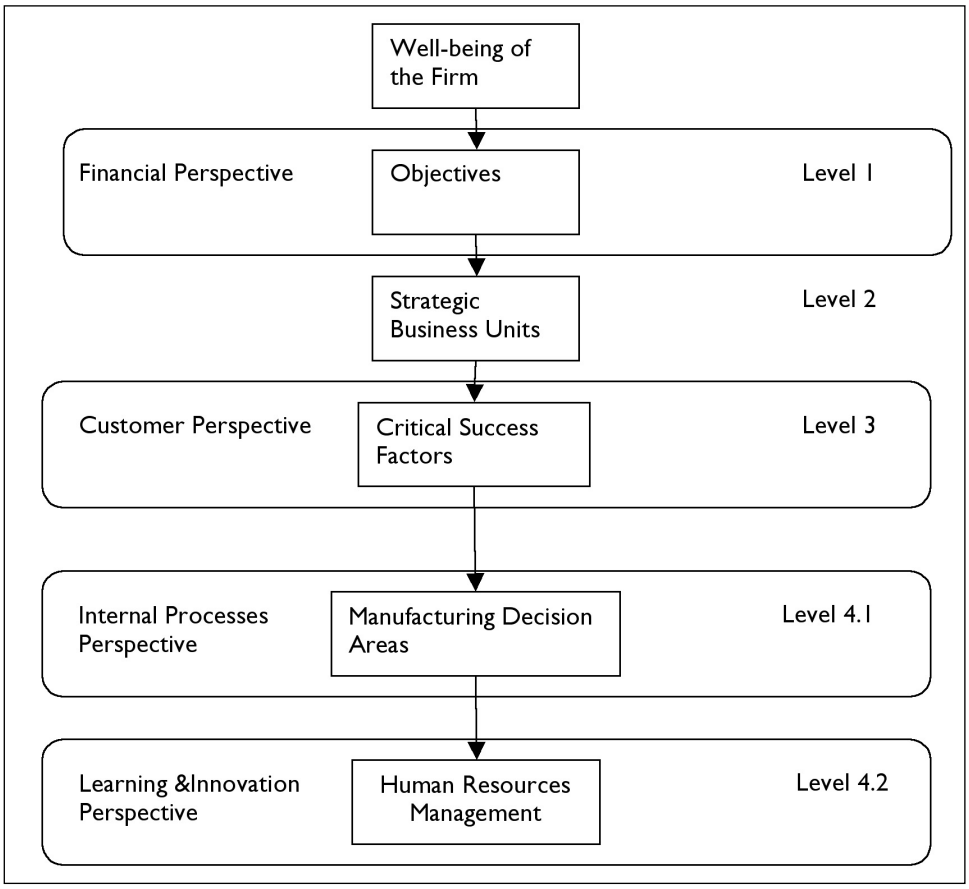

Figure 2: Conceptual Model for Generating Manufacturing Performance Measures

- Assignment of weights to Objectives (using AHP)
- Identification of strategic objectives.
- Identification of Strategic Business Units
- Identification of Critical Success Factors
- External Analysis of Strategic Business Units
- Assignment of weights to Strategic Business Units (using AHP)
- Assignment of weights to Critical Success Factors (using AHP)

2. Evaluation of Manufacturing Decision Areas
   - Assignment of weights to Manufacturing Decision Areas (using AHP)
   - Identification of strategic objectives for Manufacturing Decision Areas
   - Generation of performance indicators for decision areas

3. Evaluation of Human Resources Area
   - Assignment of weights to Human Resources Management Area (using AHP)
   - Identification of strategic objectives for Human Resources Management Area

- Generation of performance indicators for Human Resources Area.

The question that arises is: How to generate the performance indicators?. The following procedure is suggested:

- Produce an assessment of every manufacturing and human resources management area regarding the degree they support the achievement of the critical success factor. It is suggested to use a -2 through 2 points Likert scale.

Let x_{ij} the support given by area i to critical success factor j (using a Likert scale).

- Let a_{ij} the weight of the area i in relation to critical success factor j, which is estimated using the AHP tools.
- Prioritize the areas by (a) the value a_{ij} in an ascending way or by (b) the term a_{ij} x_{ij} in a descending way. In the first case, it is given higher priority to those areas which are more important (higher weight). In the second case it is given a higher priority to those areas in which have more importance and have lower performance.
- Select those areas that are more important, according to the priory given in the last step.
- Define strategic objectives for those selected areas.
- Once the strategic objectives for the manufacturing decision areas and the human resources management area have been identified, the performance indicators are defined according to the Balance Scorecard approach.

It should be noted that the strategic objectives are only defined for the manufacturing area and the human resources management, because the objective of the conceptual framework is only to produce performance measurements for the manufacturing area. However, it is also possible to define strategic objectives for the long term objectives and critical success factors using the same procedure.

SELECTION OF PERFORMANCE INDICATORS

The process described above may lead to a large number of performance measures. Considering the suggestion made by Kaplan and Norton (2000) that each perspective should contains only 4 to 6 measures, a procedure to reduce the number of them is proposed. However, for the case of the internal processes 4 to 6 measures will be considered by manufacturing decision area. This is because; the aim is not the generation of performance measures exclusively at a strategic level.

The reduction of the number of measures may be reduced using any of the available multi-attribute rating system. Valiris et al**.** (2005) propose the use of the simple multi-

attribute rating technique (smart) to select performance measures. They argue that it the smart technique is better than the analytic hierarchy process (AHP). In spite of the criticisms they argue, AHP is used in this work to select indicators, to be consistent with the methodology to formulate manufacturing strategies and because AHP has a solid scientific base.

Once a set a measures is obtained for each perspective, a weight is assigned to each measure using a pair wise comparison. To do the comparison, the right question to ask is: How much important is indicator X than indicator Y for measuring the objective Z? Z is a strategic objective in the framework defined by Kaplan and Norton (1990).

A hierarchical model is built, as shown in Figure 3. The nodes referred as M, represent measures. The model allows the selection of those performance measures with a high global weight.

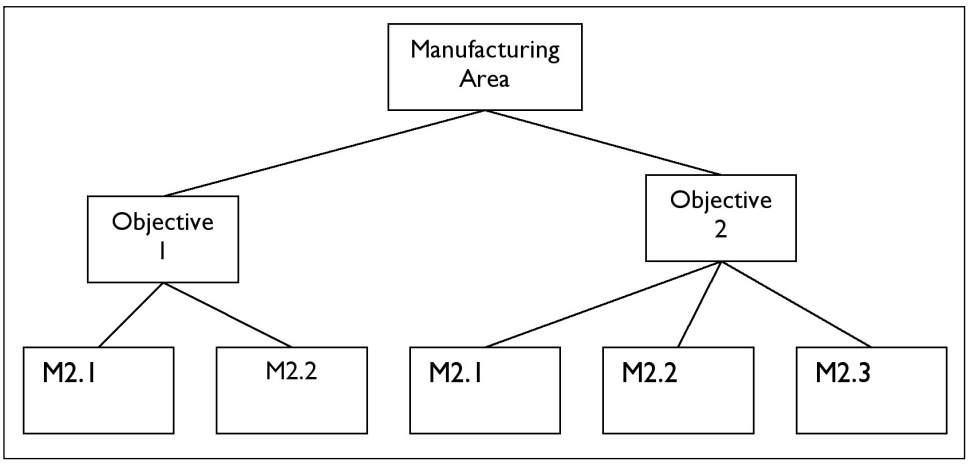

Figure 3: Hierarchical Model for the Selection of Performance Measures.

Finally, an explicative framework covering the complete conceptual model is depicted in Figure 4. It shows the relationship between the AHP model and the 4 perspectives of the Balanced Scorecard.

A stage not include in this paper is the application of this conceptual framework in companies, which is the only way for testing its validity.

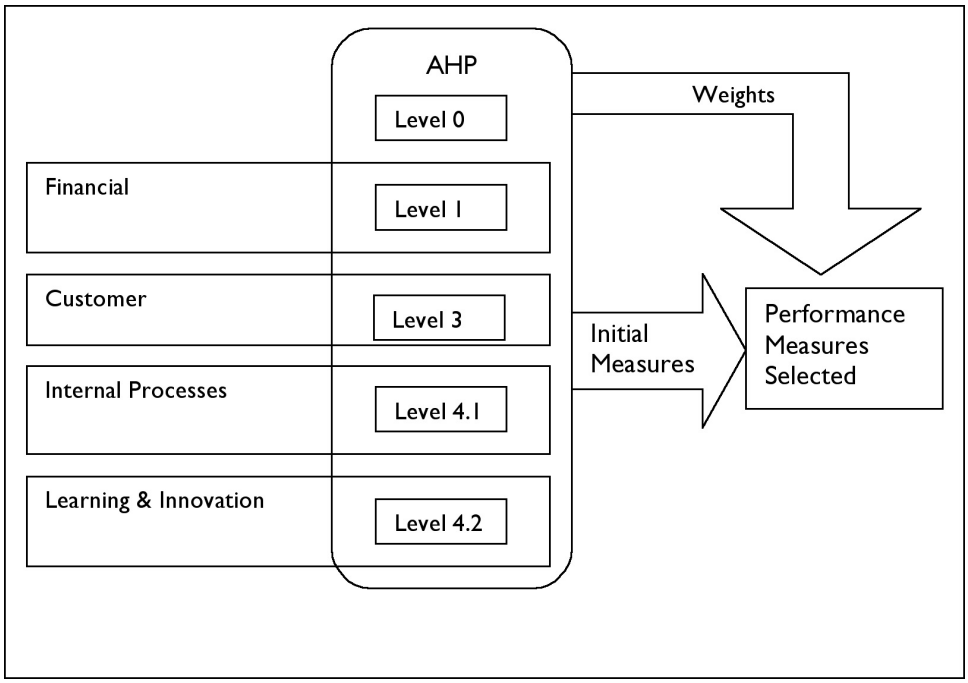

Figure 4: General Description of the Methodology

CONCLUSIONS

This research has led to the formulation and selection of manufacturing performance measures. This allows a practical approach for the manufacturing companies to determine performance indicators for the manufacturing area for controlling and managing their key external and internal processes.

The conceptual model developed is a combination of a methodology for formulating a manufacturing strategies and the Balanced Scorecard. They are used to generate an initial set of performance measures.

The Analytic Hierarchy Approach is used to select a reduced number of measures, in order to obtain a number of them that can be managed by the people in charge.

The work presented here is only a conceptual model. It does not attend to propose a new approach, but to create a practical tool to produce manufacturing performance measures.

One of the limitation of this work, as well the one carried out by Valiris et al**.** (2005), is that the an additive model is used to relate the levels of the hierarchy. The underlying assumption is that all the nodes of the model of the same level are independent, which

is not necessary true. For example, the achievement of one objective may influence the achievement of other objective of the same level. In fact, those types of relationships are admitted by the Balanced Scorecard and are incorporated in what Kaplan and Norton (2000) call Strategic Maps. A tool that would solve this situation is the Analytic Network Process (ANP) which was also developed by Saaty (1996b). In this contest, Yurdakul (2003) proposes a model based on ANP to measures the performance of manufacturing. However, it considers pre-defined performance indicators, so the paper describes a way of assigning priorities to given indicators and a way to construct them is not presented.

If the process described is carried out regularly, the weight of the manufacturing and human resources areas may change, which means that the performance indicator may change. This means that the performance indicators used will vary along the time.

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Biography

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Heuristic Algorithm for Workforce Scheduling Problems

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Abstract

In this paper we present a heuristic approach for solving workforce scheduling problems. The primary goal is to minimize the number of required workers given a pre-established shift demand over a planning horizon. The proposed algorithm starts with an initial solution (initial number of workers and their shift assignment) and iteratively searches the state space, moving towards better solutions via a local search procedure. Local optima are avoided by guaranteeing that the algorithm never returns to a previously visited solution. The algorithm stops after a termination criterion is met. The solution provides a detailed schedule of each worker on each shift. A number of constraints such as minimum and maximum number of working hours, rest days, and maximum number of continuous working hours are considered. The algorithm was tested on a number of randomly generated problems of different sizes. A Mixed Integer Programming (MIP) formulation is proposed and used as a benchmark. Computational experiments show that the algorithm always found optimal or near-optimal solutions with significantly less computer effort.

Keywords: Workforce scheduling, shift scheduling, heuristics, shift assignment.

INTRODUCTION

The Workforce Scheduling Problem (WSP) is related with a number of topics which include shift design, days-off scheduling and workload assignment. Workforce scheduling is important to maximize profits without sacrificing the staff's efficiency. Related research (Best, 1991) shows that workforce schedules affect both health and social life of workers. Hence it is important to establish workforce schedules that both reduce costs for the organization and that guarantee adequate work conditions.

This in order to decrease the possibilities of work related accidents or have a negative effect on the daily activities performance of the workers.

A number of applications of workforce scheduling problems are commonly found in every day life. These include scheduling of airline crews, hospital staff, call-center receptionists, public transportation, and industrial plants. This paper deals with the shift assignment problem. This scheduling problem consists of determining the optimal personnel assignment to a set of pre-determined shifts subject to legal and organizational constraints. Instances of this WSP are usually NP-Hard. In small cases, exact solutions are possible to find with mathematical programming. However, in real cases heuristic approaches are required to obtain near-optimal solutions in reasonable computing times.

In this paper we developed a local search heuristic algorithm to solve the problem of finding the minimum number of workers required to meet shift demands over a planning horizon. A number of constraints are considered which include the minimum number of working days in a week, the assignment of workers to non-consecutive shifts, etc. The resulting solution also shows the assignment of workers into the predefined shifts. We developed a procedure to test the proposed algorithm, which is the use of a Mixed Integer Programming (MIP) formulation.

WORKFORCE SCHEDULING DEFINITIONS

Shift. A shift is defined as the period of time in which a group of workers are on duty. The shift definition includes the starting and finishing times (Musliu, 2001).

Workforce. Workforce is defined as the required number of workers to satisfy a shift demand (Musliu, 2001).

Planning Horizon. The planning horizon (P) is considered the time period in which the workforce is assigned to different shifts (Musliu, 2001).

Cyclic schedules and non-Cyclic schedules. A cyclic schedule is such that the workforce is initially scheduled for a pre-defined planning horizon: In the second cycle, the first worker takes on the schedule of the second; the second one takes on the schedule of the third one, and so on. The length of the cycle will be equal to the number of workers. In the example shown in table 1 the length of the cycle is five. The cyclic schedule guarantees that all the employees work the same number of hours, but in this type of schedule it is more difficult to take into account worker needs and special requirements in the moment of establishing a workforce assignment. In non-cyclic schedules the workforce assignment is done every P periods of time according to worker and company needs.

Shift assignment. This is the assignment of workers to shifts previously established. Table 1 shows an assignment of 5 workers to 3 shifts during one week.

Table 1. Example of workers assignment to shifts (Taken from Musliu (2001))

Employee/ day	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
1	M	M	M	M	A		
2	A	A	A	A			
3	N	N	N	N	N		
4	A	A	A			N	N
5		M	M	M	M		

Shifts	
M	Morning
A	Afternoon
N	Night

Rotating Workforce Scheduling. It is the assignment of workers to shifts in a cyclic schedule (Musliu, 2001).

Feasible shifts. A shift is feasible when all workers can be assigned meeting all constraints. Typical constraints are the maximum consecutive workdays or the minimum/maximum daily hours a worker can be assigned, etc.

PREVIOUS WORK

The aforementioned problem can be classified as a Rotating Workforce Scheduling Problem (RWSP). This problem consists of finding the optimal assignment of shifts and work days for each worker. Researchers have taken different approaches to solve this problem. Balakrishman and Wong (1990) solved this problem by using network flow formulations. Lau considered (1996a) the shift assignment problem subject to personnel demand and shifts change constraints and proved that this problem is NP – complete. Later Gartner and Wahl (1998) proposed heuristics to solve for the manual construction of rotating workforce schedules. Brusco and Jacobs (1993) developed a Simulated Annealing approach to solve a cyclic staff scheduling problem. Hung (1993) proposed a simple algorithm to solve the problem of assigning workers into shifts, but considering that a worker comes to work 3 days per week. Later the same author (Hung, 1994) extended his previous work on this subject by considering that

worker comes to work 4 days per week. The analysis seeks to minimize the workforce size subject to satisfying staffing requirements on weekdays and weekends, and work rules relating to shift changes, off-days, and off-weekends. Jackson, Dollard and Havens (1997) developed a procedure to solve the workforce scheduling problem considering employees with different skills and shifts with specific skills requirement. Aykin (1998) developed a branch and cut algorithm for optimal shift scheduling with multiple breaks and break windows. Laporte (1999) considered developing rotating workforce schedules by hand showing how the constraints can be relaxed to obtain acceptable schedules. Musliu (2001) solved this problem using backtracking algorithms obtaining better results than those of Balakrishman and Wong (1990). Recently, Mejía and Montoya (2007) proposed a Petri Net based algorithm to minimize workforce requirements in systems with precedence and shift length constraints.

PROBLEM DESCRIPTION

In this paper we intend to find the minimum cost workforce assignment for a cyclic schedule. The input data for this model are the predefined shifts, the number of shifts, and the hours in which each shift takes place.

Variables

W: Total number of workers.

$w^+_{i,k}$: Excess of workers on the shift i of the day k.

$w^-_{i.k}$: Shortage of workers on the shift i of the day k.

Input data

c_w: Unit cost per worker(salary).

c_e: Cost of excess per worker and per shift.

c_s: Cost of shortages per worker and per shift.

W_0: Initial number of workers.

$W_{i,k}$: Personnel demand in the shift i of the day k.

s_k: Number of shifts in day k.

D_c: Maximum number of consecutive workdays a worker can be assigned.

M: Number of workdays that a worker must be assigned in one week.

N: Number of workdays in a week ($N \geq M$).

Assumptions

(i) The week has 7 working days (N=7).

(ii) Either shortages or excess of workers are allowed in a shift.

(iii) There exists a minimum and a maximum hours per day in which a worker can be assigned.

(iv) The total worker demand in each shift is known.
(v) Shift overlaps are not allowed.
(vi) The size of the workforce must satisfy at least the minimum of the daily personnel demands.
(vii) All workers must work exactly M days of the week, even if this results in excess of workers in some shifts.
(viii) The planning horizon (P) is one week

Objective function

$$(c_w \times W) + (\sum_{k=1}^{N} \sum_{i=1}^{s_k} c_e \times w^{+}{}_{i,k}) + (\sum_{k=1}^{N} \sum_{i=1}^{s_k} c_s \times w^{-}{}_{i,k})$$

Constraints

The following can be typical constraints to this problem:
(i) A worker must work at most M days in a week.
(ii) A worker can work at most d_c consecutive days.
(iii) A worker must rest at least a given number of hours between shifts.
(iv) A worker must work at most a given number hours in a day.
(v) A maximum number of shortage/excess of workers is defined.

PROPOSED ALGORITHM DESCRIPTION

The proposed algorithm starts with an initial solution, which consists of (i) an initial number of workers (ii) the assignment of such workers into shifts. Normally it is expected that the cost of shortages (c_s) is greater than the cost of per worker (c_w) and that the cost of excess (c_e) is greater than cero. In this case, if the assignment of workers results in no shortages or excess of workers, the solution is optimal and the algorithm stops; if not, a new worker is brought in and the workforce is re-assigned into shifts. Every time a worker is brought in, a new solution and value of the objective function are calculated and the best solution is stored. This procedure is repeated until a termination criterion is met.

Notice that a feasible solution with neither excess nor shortage of workers may not be the minimum cost solution because it depends on the values of c_w, c_e, and c_s. Thus, a zero shortage and zero excess of workers cannot typically used as a termination criterion. Usually, the algorithm terminates after a pre-defined number of iterations.

Initial Solution (S_0)

The initial solution (S_0) corresponds to the initial number of workers (W_0) and their initial distribution over the shifts and workdays. The procedure to distribute W_0 consists in assigning each employee progressively into each shift until completing the personnel demand for that shift. If it is not possible to satisfy demand due to shortages of available workers, the maximum number of available workers is assigned to that shift.

If all workers can be optimally assigned (i.e. no worker shortage or excess at all shifts) the algorithm stops. The objective function $C_{best} = C_{initial}$ is calculated and the current solution is stored $S_{best} = S_{0.}$

The only pattern to find the initial number of workers W_0 is given by the values of the personnel demand, but the costs (c_s, c_w, c_e) influence the value that should be assigned to W_0.

Typical results show that if $c_w > c_s$ it is very possible to obtain a solution with shortages. In this case W_0 is taken as the minimum worker requirements over the daily demands.

On the other hand, if $c_w < c_f$ it is very possible to obtain a solution with no shortages. If shortages are not allowed at any shift, the initial number of workers can be set either as the maximum or the average number of workers over the daily demand.

Depending on the value of c_e a solution with excess of workers might be obtained in some of the shifts.

In the case where c_e is a very large value in comparison to the other costs and if $c_w < c_s$ it might be viable to try with both the maximum or the average number of workers over the daily demand.

Iterative Procedure

1. Given an initial solution S_0, bring in a new worker w'.
2. Assign the new worker w' to those shifts with the greatest shortages.
3. If the worker w' completes M workdays a new solution (S_{new}) was found and go to step 7 ; if not go to step 4:
4. For the new worker w', select a feasible shift s_a with no shortages and with the minimum excess of workers. Check if another worker w_a already assigned to this shift, can be assigned to a feasible shift with shortages s_b.
5. If such a worker exists, the new worker w' is assigned to the s_a shift and worker w_a is assigned to the shift $s_{b.}$ If not, the new worker w' is assigned to s_a.
6. Go to step 3.
7. Calculate the objective function value C_{new} of the new solution S_{new}.
8. If $C_{new} \leq C_{best}$ then $S_{best} = S_{new}$, and $C_{best} = C_{new.}$
9. Go to step 1 until the termination criterion is met.

Termination criterion

The termination criterion consists of establishing a limit number of iterations (N_{max}). Several trials are needed to establish the N_{max} number, depending on the available CPU time and the desired solution quality.

The following example (example 1) shows the execution of the algorithm. Figure 1 (shown below) describes the proposed algorithm iterative procedure.

Step 1:

Initial solution (S_0): Let an initial solution with W = 5 workers assigned to meet the demand in three shifts per day, considering two work days and that a worker can work at most two consecutive days and can not be assigned to more than one shift per day.

First each worker is progressively assigned into shifts until meeting the personnel demand for each shift. For example, workers 1 and 2 are assigned to the Monday morning shift. Next workers 3 and 4 are assigned to the Monday afternoon shift and so forth. Notice that with five workers it is not possible to meet the demand on the Tuesday night shift. Table 2 shows the initial assignment of each worker into the morning (M), Afternoon (A) and night shifts (N) of the two work days (Monday and Tuesday) considered in this problem.

Table 2. Initial workforce assignment to shifts

Day	Shift	Worker demand	Assigned Workers			Shortage of workers per shift	Excess of workers per shift
Monday	M	2	1	2		0	0
Monday	A	2	3	4		0	0
Monday	N	1	5			0	0
Tuesday	M	3	1	2	3	0	0
Tuesday	A	1	4			0	0
Tuesday	N	2	5			1	0

Step 2:

Since this assignment implies a shortage of workers, a new worker is brought in (W=6) and she is assigned initially to the night shift of Tuesday which is the only shift with shortages. Table 3 shows the assignment of the workforce until this step.

Table 3. Temporary workforce assignment to shifts

Day	Shift	Personnel demand	Assigned Workers			Shortage of workers per shift	Excess of workers per shift
Monday	M	2	1	2		0	0
Monday	A	2	3	4		0	0
Monday	N	1	5			0	0
Tuesday	M	3	1	2	3	0	0
Tuesday	A	1	4			0	0
Tuesday	N	2	5	6		0	0

Step 3:

Since the new worker has to work two days and she has been assigned to only one workday, it is necessary to go to steps 4 and 5:

Steps 4 and 5:

In this step the new worker (worker 6) is assigned to a feasible shift with no shortages and with the minimum excess of workers. In this case all the shifts have no shortages and no excess of workers per shift. Considering the constraint that establishes that a worker can not be assigned to more than one shift per day, the feasible shifts in which worker 6 can be assigned are the morning, afternoon and night shifts of Monday. In this case the morning shift of Monday is chosen, because it is the earliest shift of the day. Table 4 shows the final assignment of the workforce.

Table 4. Final workforce assignment to shifts

Day	Shift	Personnel demand	Assigned Workers			Shortage of workers per shift	Excess of workers per shift
Monday	M	2	1	2	6	0	1
Monday	A	2	3	4		0	0
Monday	N	1	5			0	0
Tuesday	M	3	1	2	3	0	0
Tuesday	A	1	4			0	0
Tuesday	N	2	5	6		0	0

Step 6:

At this point all workers complete two workdays. Thus it is necessary to go to steps 7, 8 and 9 where the new value of the objective function is calculated (step 7). The actual best solution is updated (step 8). Step 9 checks whether the termination criterion (number of iterations) is met.

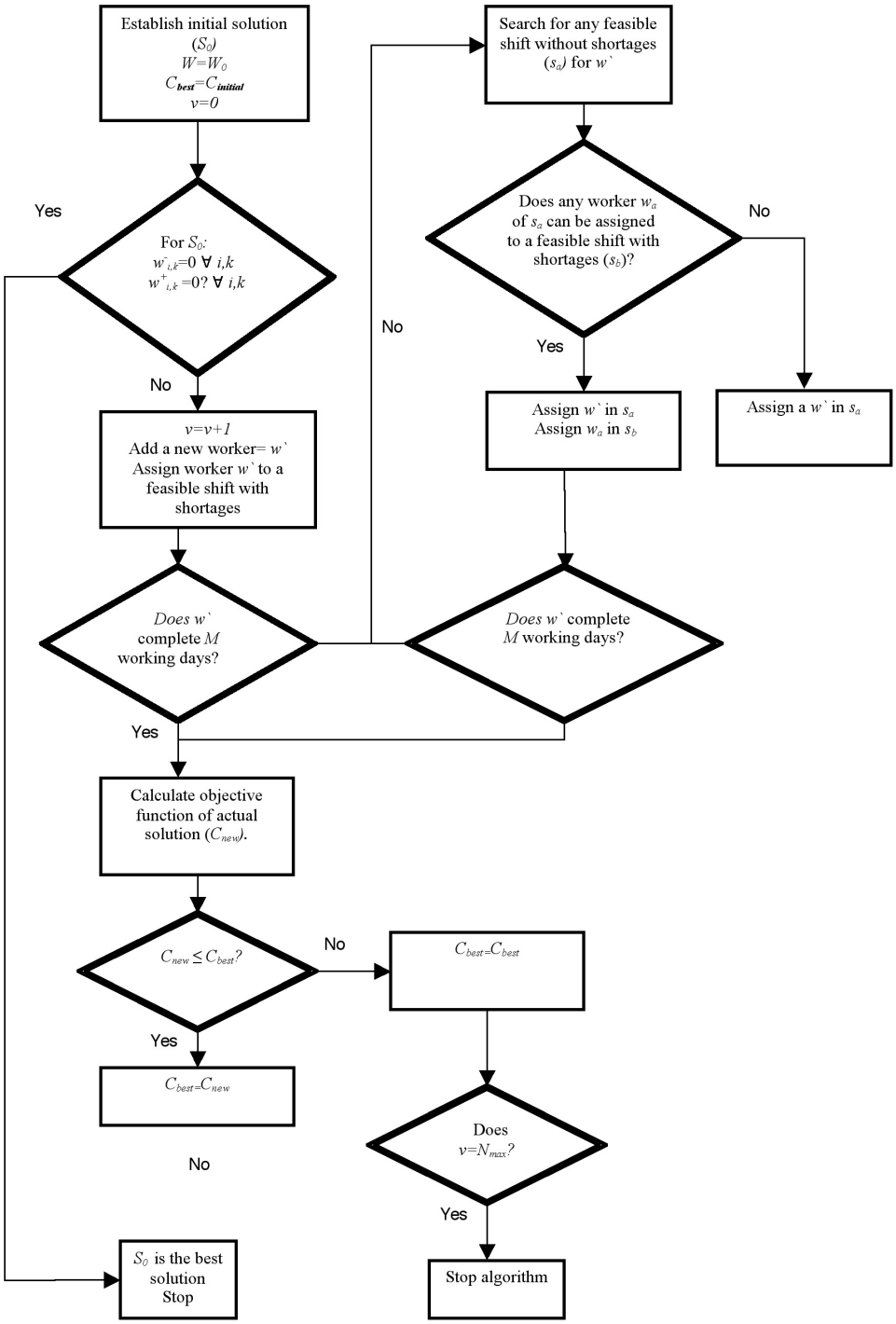

Figure. 1. Flow Diagram of the algorithm.

To summarize: In the example 1 the initial solution includes shortages in the night shift of Tuesday, so an extra worker is added. She is assigned to this shift and also she is assigned in another shift to complete M working days, incurring in an excess of workers in the morning shift of Monday.

ALGORITHM PERFORMANCE

The proposed algorithm was implemented in VISUAL BASIC and run on a PC having 512Mb RAM.In order to study the performance of the proposed algorithm, we formulated a special instance of this problem as a Mixed Integer Program (MIP). In this instance, the number of shifts in every day of the week is the same and shortages are not allowed at any shift. This formulation takes the number of workers and the number of shifts per day as input data. This MIP formulation was written and run in GAMS®. We used a set of randomly generated test problems.

MIP Formulation

$$\text{Min} \sum_{j=1}^{W} \sum_{k=1}^{N} \sum_{i=1}^{T} x_{i,j,k}$$

s.t

$$[1] \quad \sum_{j=1}^{W} x_{i,j,k} \geq W_{i,k} \quad \forall i = 1,2,...T; \quad = 1,2,...N$$

$$[2] \quad \sum_{i=1}^{T} x_{i,k,j} \leq 1 \quad \forall k = 1,2,...N; \quad \forall j = 1,2,...W$$

$$[3] \quad \sum_{k=1}^{N} \sum_{i=1}^{T} x_{i,j,k} \leq M \quad \forall j = 1,2,.....W$$

$$[4] \quad \sum_{i=1}^{T} x_{i,j,k} + \sum_{i=1}^{T} x_{i,j,k+1} + ... \sum_{i=1}^{T} x_{i,j\ k+D_c} \leq D_c \quad \forall k = 1,.....N; \forall j = 1,.....W$$

$$[5] \quad x_{T,j,k} + x_{1,j,k+1} \leq 1 \quad \forall k = 1,...N; \quad \forall j = 1,.....W$$

$$[6] \quad x_{i,j,k} \in \{0,1\} \quad \forall j = 1,2,...W; \quad \forall i = 1,2,...T; \quad \forall k = 1,2,...N$$

Where:

N: Number of workdays in a week.

$W_{i,k}$: Number of workers required in the shift i of the day k.

W: Total number of workers.

T: Number of shifts per day.

d_c: Maximum number of consecutive workdays a worker may be assigned.

M: Maximum number of workdays in a week.

$$x_{i,j,k} \begin{cases} 1 \text{ if the employee j is assigned to the shift i of the day k.} \\ 0 \text{ otherwise} \end{cases}$$

Explanation of the constraints

1. This set of constraints establishes that the personnel demand of the shift i of day k must be satisfied.
2. This set of constraints establishes that a worker may work at most one shift per day.
3. This set of constraints establishes that a worker may work at most M days per week.
4. This set of constraints establishes that a worker may work at most d_c consecutive days per week.
5. This set of constraints establishes that a worker may work at most M days per week.
6. This set of constraints establishes that a worker cannot be assigned in the last shift of one day k and in the first shift of the next day (k+1).

Establishing the optimal MIP solution

1. Set the total number of workers W as the best number of workers obtained with the algorithm allowing no shortages.
2. Find the optimal solution to the MIP formulation.
3. Set W = W - 1 and solve again the MIP problem. If the new problem is infeasible then the minimum number of workers was found with the algorithm; if a new optimal solution is found, the solution obtained with the algorithm was not optimal because the demand could have been met with fewer workers.

Results

We tested 10 different problems using both the mathematical formulation and the algorithm. The termination criterion for each problem was 100 iterations. These problems were randomly generated considering different ranges of personnel demand per shift, different maximum number of consecutive days and different number of shifts per day. Table 5 shows a description of the sizes of the tested problems:

Table 5.Description of the sizes of the tested problems

Problems	M	d_c	T	Range of demand per shift
Problem 1	5	4	3	30-80
Problem 2	5	3	3	30-80
Problem 3	5	4	3	115-170
Problem 4	5	3	12	30-45
Problem 5	5	3	12	65-85
Problem 6	5	3	8	115-150
Problem 7	5	3	3	295-445
Problem 8	5	5	5	18-25
Problem 9	5	5	6	10-20.
Problem 10	5	5	2	15-25

Table 6 shows the results obtained in all tested problems with both the proposed algorithm and the MIP solution:

Table 6 Proposed algorithm and the MIP solution results

	Proposed Algorithm Results			MIP Results	
Problems	W0	Best Solution(W)	CPU Time (sec)	Optimal Solution(W)	CPU Time (sec)
Problem 1	214	217	15	217	50
Problem 2	202	227	23	227	90
Problem 3	567	568	10	568	150
Problem 4	645	655	210	655	570
Problem 5	1269	1275	253	1275	2700
Problem 6	1492	1515	230	1515	2040
Problem 7	1506	1528	170	1528	310
Problem 8	143	144	45	144	20
Problem 9	110	111	40	111	15
Problem 10	70	70	20	70	10

CONCLUSIONS

The results show the validity of the proposed algorithm: In at least 10 tested problems we obtained the optimal solution. However, it is necessary to consider more scenarios than the ones considered in the MIP, so it was not possible to make a more profound and detailed analysis about the performance of the algorithm, but certainly we could establish that the proposed algorithm is able to obtain very good results making it a viable tool to implement.

The solutions obtained with the algorithm vary with the initial number of workers: However using the criteria and values suggested above to determine the initial number of workers, we always found the optimal solutions.

The algorithm shows good behavior in terms of execution times: In almost all the tested problems the execution times were significantly shorter than the ones obtained with the MIP solver. The greater differences in the execution times occur in the more complex and larger problems.

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Biography

Carlos Montoya is currently an instructor at the industrial engineering department at the Universidad de los Andes in Bogotá, Colombia. He received a B.Sc degree in Industrial Engineering from the Universidad de Los Andes, Bogotá, Colombia (2005), and a M.Sc. degree in Industrial Engineering from the Universidad de Los Andes (2007). He has also worked as academic and research assistant between 2005 and 2007. His research interests include Production Scheduling, Workforce Scheduling and applications of AI in Production Systems. He has published papers on production systems in domestic and international conferences and currently he has two papers under review in international journals and one already accepted for publication.

Gonzalo Mejía is currently an assistant professor at the industrial engineering department at the Universidad de los Andes in Bogotá, Colombia. He received both his B.Sc and M.Sc degrees from the same university and his PhD from Lehigh University in 2003. His research is concentrated on manufacturing systems modeling and scheduling. In particular, he is focused on Petri net modeling approaches for hierarchical modeling of real-life manufacturing systems. He teaches both at the undergraduate and graduate level. He also has participated in the development of industrial scheduling systems. He is a member of IIE.

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Importance Level of Success Criteria in Management Consulting Operations: The Turkish Case

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Abstract

The purpose of this study is to determine the importance level of success criteria in management consulting operations in Turkey. A survey instrument was developed and posted on the Internet in order to reach as more respondents as possible for the study. A Likert scale of 10 was chosen to explain precisely the differences between the criteria. Eighty responses were returned. It should be stated that the respondents of the survey were all Turkish consultants. Descriptive statistical analyses were conducted for the four main categories and their criteria. On the basis of a literature search, it was found reasonable to classify the success criteria for management consulting operations into four basic categories such as human resources, competitiveness, customer relations, and processes and methods. The study presents the ratings of four basic categories and their criteria, which essentially affect the success of consulting firms. The results of the research will serve consulting companies as guidelines to pinpoint improvement areas in their consultancy operations. The responses received from the consultants can be considered reliable and satisfactory. In addition, the important point that this study has revealed is the interest and willingness of the consultants for further studies.

Key words: Consultancy operations, Turkish consultants, success criteria.

INTRODUCTION

As a result of intensifying global competition and technological developments, it is inevitable for companies to demand assistance of consulting companies. As demand for consulting services increases, competition among the consulting firms tend to

increase. These developments have been observed very frequently in consulting industry in recent years. As an outcome of increasing demand for consulting services, the number of consultants offering assistance boomed. However, consulting firms require more refinement in their consultancy work.

Management consulting industry has different divisions ranging from human resources to information technologies and from quality practices to re-engineering. The tasks that different kinds of consulting firms perform are almost irrelevant and it is quite difficult to find a common practice. However, the task they all perform is project-based so that there are some common factors influencing the success of consulting firms. The following criteria are not all of the criteria that influence the success of consulting firms, but they are specific for consultants differing from the criteria of other organizations.

THEORETICAL BACKGROUND OF CONSULTING OPERATIONS

On the basis of a literature search, it has been found reasonable to classify the success criteria for management consulting operations into four basic categories such as human resources, competitiveness, customer relations, and processes and methods. The basic categories and their criteria are discussed in the following paragraphs.

Human resources

"Human resources" is pointed out as the basic input for consulting firms. Independent from all other factors, staff working in a consulting firm is the main factor for determining its success. A consulting company knows as much as its staff knows; a company has the capabilities that its staff possesses (Matassani, 2000). Although it is important how efficient and effective the processes or other resources for the project are, the basic category to determine success is "human resources." Criteria that constitute "human resources" in this study are knowledge, skills, people, and effective usage of the professional staff (Chase, et al, 2004).

(a) Knowledge

For management consulting firms, knowledge is a critical property that the consulting firms sell. Every project accomplished is based on knowledge beside skills and expertise. Knowledge can also be a combination of theory and methodology such as EVA (economic value analysis) that helps managers think more rigorously about their actions (Matassani, 2000).

(b) Skills

Skills of a consulting company can be various and can be related to simple problem-solving approach. As Bill Matassani states the skills that a consultant needs are related

to communication, project management, people development, and interaction with senior management to keep them involved in the project (Matassani, 2000).

(c) People

For consulting firms, "people" is the synonym of leadership, values, commitment, professionalism, and trustworthiness (Matassani, 2000). A good combination of knowledge and skills can be sufficient for good impact, but they certainly have important effects on the project and the results obtained.

(d) Effective Usage of the Professional Staff (Efficiency)

David H. Maister identifies consulting firms as a shop where the right kinds of "machines" (professional staff) must be correctly allocated to the right kinds of jobs (consulting projects). Most of the consulting firms are engaged in multiple projects at the same time, which requires the partners, midlevel and junior consultants to be carefully distributed among the projects in order to sustain efficiency staff (Chase, et al, 2004).

Competitiveness

The second category is "competitiveness." As it is mentioned above, increasing competition among client companies requires consultancy more than ever. This also results in enhancement of competition in the consulting industry so that the competition among consulting firms is getting increasingly more intense. Basic criteria that constitute "competitiveness" of a consulting firm are being among best in at least one service, strong image and reputation, and diversification of services (David, 2001).

(a) Being among the best in at least one service

Being among the best in at least one service is one of the factors that most affects competitiveness of a consulting firm. Besides, the competitive strength of being the best, the practice results in reputation. Mouth to mouth effect plays an important role in the advertisement and promotion of the firm. A service that is among the bests can be an effective core competency and driving factor for a consulting firm.

(b) Strong image and reputation

Increasing competition in the globalization, one of the most important assets of a consulting company is its strong image and reputation. The company managers utilize good reputation or image as one of the main evaluation criteria for management firms. Hence, marketing message requires special attention (David, 2001). Inconsistent marketing efforts end up with inconsistent results and unnecessary workload.

(c) Diversification of services

Consulting firms become more aware that a key factor to sustained success is

diversification. By varying the industries served, services offered, and geographical areas reached, consulting firms become better to serve the needs of their clients. Diversification is also an important tool in capturing bigger market shares in consulting. Besides, diversified services lead to ability of serving to different markets and needs. This ability will obviously result in serving to various markets that mean more customers and higher shares in the market. Because diversification leads to engagement with different markets, it also has a positive effect to the reputation of the firm. As the consulting firm is engaged with more people in different areas, advertising and recognition will be much better.

Customer relations

"Customer relations" is the third category. It will not be an exaggeration to say that it is the category that lies at the base of each project. Unless strong customer relations with a client are not achieved, the business will finally fail. Besides, customer relations constitute the basic point where consulting firms can create differences from their competitors (Congram and Dumesic, 1986). The criteria suggested for this category are trust relationship with clients, customer-driven growth strategy, cooperation with client in finding solutions (Hoban, 2002), informing client regularly and frequently, clear expression of capabilities, full support of top management, and consideration of client's willingness and ability (Fisher and Rabaut, (1992).

(a) Trust relationship with clients

For a consultant, to work effectively with any company requires the establishment of a trusting relationship. It will not be an exaggeration to say that a consulting firm's success is dependent on a relation with its clients based on trust. A company acquires the project if the client trusts. Trust first of all is related with consulting firm's abilities, skills, knowledge, professional staff, and reputation. When it comes to a trust relationship, the main factor is openness during the entire project activities.

(b) Customer-driven growth strategy

In order to gain competitive advantage, consulting firms should always endeavor systematically to acquire information and insight from the current, former and future clients. A customer-driven firm, as a result of its investment in service quality, benefits as its satisfied clients purchase additional services, recommend and refer to their business, and stimulate firm growth (Congram and Dumesic, 1986). Clients' identification of the specific service strengths and weaknesses of a firm can be useful in the enhancement of service delivery systems, human resources, marketing, and internal marketing. This is essential for customer-driven firms as a foundation for effective marketing and growth.

(c) Cooperation with clients in finding solutions

Analysis of the consulting firms reveals that every consulting firm interacts with its clients, but the degree of interaction varies significantly from one firm to another. Many consultants have relatively little interaction with the clients and some simply provide direction. They identify their clients' critical issues and then tell them how to resolve them. Others take action by addressing only those issues the client has specified (Fisher and Rabaut, (1992). The most effective consultants are those who work together with the client in every step of the task to define key issues and implement solutions.

(d) Informing client regularly and frequently

Consulting projects are usually considered to be mainly within the domain of the consultant. Consultants accomplish their task and then deliver the result to their clients. The clients, with little opportunity to develop their own insights or the skills needed to implement the recommended changes and busy with all the other aspects of their routine jobs, are nevertheless expected to be able to implement the consultants' recommendations (Schaffer, 1997).

(e) Clear expression of capabilities

One of the greatest challenges facing consultants is to manage client expectations. If not the clients may lead to bad feelings and prefer write-offs, slow payments, and worse do not repeat business (David, 2001). In order to avoid such outcomes, a consulting company should identify the services that carry the most significant risk of wrong expectations and make it a point to give those areas special attention when outlining the engagement to the client.

(f) Full support of top management

According to Alison Nankivell, closely held family companies can create problems for consultants. If some of the parties involved in the problem believe that there is no need for outside advice, it can be a nightmare for both the company and the consultant. To ensure success of the project, top management involvement must begin at the very start of the consulting engagement. Together, the consulting team and senior executive team must define clear and realistic expectations for the project. And also they must agree on the milestone markers and performance indexes that will be used to track progress (Fisher and Rabaut, (1992).

(g) Consideration of client's willingness and ability

For consulting profession it is quite common to hear consultants complain about organizational barriers preventing their clients for achieving good results from their recommendations. A client rejecting a carefully developed marketing plan because it

contradicts the CEO's beliefs or a company setting a major strategy study because it calls for directional shifts too radical for senior management to risk, are some examples of what usually takes place in consulting operations (Schaffer, 1997).

Processes and methods

The last category that affects consulting success is "processes and methods." Provided that all previously mentioned success categories are accomplished at optimum levels of success, a consulting firm cannot work efficiently and effectively without achieving successful processes and methods. Without effective processes and methods, even the previous categories cannot be accomplished. The "processes and methods" category mainly is consisted of the following basic criteria such as continuous learning, tangible results and changes, future thinking, serving in shortest time possible, teaching fishing rather than giving fish, innovation, definition and clear understanding of goals and reasons of the project, incremental successes instead of one big solution, considering the implementation process as well as suggestions, and obtaining answers to main questions (Schaffer, 1997).

(a) Continuous learning

Continuous learning is a factor that consulting firms must handle seriously. As a result of tough competition, each day a new approach is developed and a new application is defined. A consultant cannot ignore these developments. In order to compete with others, they have to improve themselves, follow the developments, and increase their knowledge.

(b) Tangible results and changes

Clients care results oriented. Despite the fact that most of the services consulting firms cannot provide results in short run, or sometimes even in the long run; client companies still tend to ask for tangible results and changes. A project's success is evaluated with tangible changes and companies still do not feel likely to engage in projects that they cannot evaluate its effects with tangible findings. In the client's eyes success is the achievement of tangible results according to specific business criteria that the client and consulting firm determine at the beginning of the consultation. According to clients "if nothing changes, nothing is accomplished" (Sam, 2000).

(c) Future thinking

Future thinking is an attribute that results from the changing nature of the management sciences. As a result of developments in science and technology, a consulting company should adopt the understanding of future thinking in all of its projects. A consulting firm must have the ability of forecasting future trends in the sector and make the necessary changes to sustain successful business.

(d) Serving in shortest time possible

In today's business environment one of the most powerful weapons that companies hold for competition is fast service. All of the processes of the companies are revised and adapted according to speed; from manufacturing to finance; from distribution to suppliers. With the increased competition in the industry, consulting firms that meet their customers' needs in a shorter time than their competitors grow faster and are more profitable. Beside the fact that competition necessitates fast service, also the costs of a consulting project are affected by the duration of the tasks.

(e) Teaching fishing rather than giving fish

According to Gary Neilson, best consultants are those who help clients do things. They guide and brainstorm but above all they coach their clients to think about the case and solve problems themselves. They teach to fish rather than give fish to eat. The product is not the achievement of the consultant, but the client (Glenn, 1985).

(f) Innovation

As the number of competitors is rising each day and the structures of competition and economy have changed, consulting business has become much more complicated and a challenging task. Consultants need to possess a much better understanding of the environment. They now need to find new approaches and frameworks that allow a senior management team to sort through the flood of information in order to find the optimal value for growth opportunities. Consultants can no longer depend on traditional benchmarks and frameworks. Success depends on developing new and innovative ways of looking at dynamic markets and identifying new opportunities to create value (Hoban, 2002). Even though few consulting firms have developed a clear strategy, process, and consistent effort to add new services and products to their practices, new products can provide a steady income stream, new clients and balance cash flow (Edwin, 1997). Patterns a client forms help it to understand the cause and effect relations. As these cause and effect relations are clear, it is easy to identify an innovation strategy and generate solutions for different industries (Lippitt, 1981).

(g) Definition and clear understanding of goals and reasons of the project

Generally, consultants define projects in terms of their expertise or products, not in terms of specific client results to be achieved. They do not consider the goals the client may have in mind when engaging a consultant. The project is generally defined in terms of the work the consultant will do and the products the consultant will deliver. Examples may be found in various publications (Schaffer, 1997).

(h) Incremental successes instead of one big solution

Another obstacle that consultants usually face is the assumption of consultants that the best way to attack any subject whether cash flow, marketing strategy, or inventory turns is to examine the entire system. Consultants almost always want to produce a big-picture solution; anything less is considered a peace meal or sub optimizing. Large-scale studies usually take too long, are very costly and result in change plans that are too complex for most organizations to carry out (Schaffer, 1997).

(i) Considering the implementation process as well as suggestions

Conventional consulting is based on the assumption that the key to progress is greater knowledge. According to this view, once the client knows what to do, the client will achieve greater success. However, real world applications suggest that this is a wrong assumption. The design of most consulting projects reflects the flawed assumptions of conventional consulting. Most are completely dedicated to providing managers with insight and ideas about change, but pay virtually no attention to helping the client effect change. In fact, client limitations in this area are generally not viewed as an appropriate focus for the consultant's attention (Schaffer, 1997).

(j) Obtaining answer to three main questions

The last criterion that has an important effect on the success of a consulting firm is whether the following questions can be answered or not. "What has changed for better?" "Is the organization moving forward?" "Did the consultant understand the company and its problems and come up with creative solutions?" These three questions also provide an overview of the project and are related to the criteria given above. If the consultant is capable of answering these three questions satisfactorily, the engagement becomes a mutually effective one, namely the client and consultant. These questions serve as a means of self-evaluation for the consultant as well as the overall project.

To ensure success of a project, top management involvement must begin at the very start of the consulting engagement. The consulting team and senior executive team must define clear and realistic expectations for the project. According to Alison Nankivell, confined family companies can create serious problems for consultants (Nankivell, 1991). If they believe that there is no need for outside advice it can be a nightmare for both the company and the consultant.

Despite the fact that most of the consulting firms are not able to provide beneficial results in the short run, or even in the long run, clients still tend to ask for tangible results and changes. Success of a project is evaluated with respect to tangible changes. Thus, companies do not feel likely to engage in projects that they cannot be able to evaluate its effects with tangible findings (Sam, 2000).

Management sciences are highly dynamic and future thinking is an attribute that results from the changing nature of the management sciences. Nowadays, one of the most important weapons that companies hold for competition is fast service. All of the processes of the companies are revised and adapted with respect to speed from manufacturing to finance, from distribution to suppliers. From this viewpoint, it is expected that they would ask for speed also in services they obtain from consulting companies.

According to Gary Neilson, best consultants are those who help clients do things. The important think is not to find a planned action, but a plan for implementation. The product is not the presentation of the consultant, but the presentation of the client (Glenn, 1985).

In the recent years, a lot of changes took place in the consulting profession. Even though few consulting firms have developed a clear strategy, process, and consistent effort to add new services and products to their practices, new products can provide a steady income stream, new clients, and balance cash flow (Edwin, 1997). As its clients represent an almost limitless laboratory, a consulting firm has plenty opportunities to innovate. Patterns a client forms helps a consultant to understand cause and affect relationships. Once the causes and effects are clear, it becomes easy to identify a strategy and transplant it in different industries and solutions (Lippitt, 1981).

Conventional consulting was based on the assumption that the key to progress was more knowledge. In other words, once the client knows what to do, the client will achieve greater success. Many studies have shown that not knowing what to do is rarely the greatest obstacle to organizational success.

MANAGEMENT CONSULTING INDUSTRY IN TURKEY

In Turkey, the management consulting industry is one of the industries required to accomplish significant achievements. Despite the huge number of consulting firms, the industry is not innovative. Analyzing the Turkish management-consulting firms, it is seen that the consulting sector is consisted of mainly "IT consulting" and "human resources consulting" firms. One of the main problems for the Turkish consulting firms is that most clients do not know how to work with consultants. They do not know much about the consultancy process. In other words, they are aware what they should expect and how they should contribute to the process. They consider consultants as wizards with magic sticks. Thus, this approach of the clients hinders consulting firms from development and specialization in more specific subjects.

Another problem in Turkey is the personal relations in choosing a consulting firm to work with. Managers usually make their decision according to their relationships instead of scientific and rational investigations. These decisions also affect the project since the consultants usually are under the pressure of these mutual relationships.

Most consulting projects fail especially because the global consulting firms practice the same projects in Turkey, which they practice in their home country, without taking into consideration the social and cultural features of Turkey. If these practices are acquired from abroad and directly applied, it usually ends with frustration. The same failure occurs if the Turkish firms receive consultancy without considering past experiences, the characteristics of the company, and the sector. In Turkey, consultants usually attempt to find a general solution that will fit everyone and everywhere.

Another problem for management consulting industry is the financial dynamics of Turkey. Because crises are quite frequent, companies cannot predict the long-term economic and financial developments in the country. Hence, they consider consulting services sometimes inappropriate.

For the local consulting firms, their global competitors constitute a great problem. As companies decide on engaging in a consulting project, they often prefer global ones just because of their reputation. They do not mind to investigate the local ones and not take into account the professional staff or the abilities of the consulting firm.

Last thing to mention about the Turkish consulting industry is that the process for becoming a consultant is so easy that anybody who decides can become one. This is one of the reasons why the number of consultants, especially human resources consultants, boomed. The undesirable effects of such consultants on the companies seeking consultancy also affect the consultancy industry in a negative way. The trust and reputation of consulting firms is strongly damaged because of such firms.

In order to eliminate this type of consultancy, the Turkish Management Consultants Institution has initiated a project called Certified Management Consultants (CMC). This program is an international benchmark from International Council of Management Consulting Institutes (ICMCI) (http://www.ydd.org.tr, 2004). The Certified Management Consultant project is as a measure of an individual management consultant's competence, objectivity, independence and professionalism (http://www.ydd.org.tr, 2004). Certain minimum requirements and a rigorous assessment procedure have to be met in order to qualify for the certificate of the CMC program. The CMC mark of excellence is used worldwide to accredit management consultants whose competency is recognized and certified by the national institutes that are members of ICMCI (http://www.icmci.org, 2004).

METHOD AND ANALYSIS

Application Process of the Survey

In order to reach as more respondents as possible for the survey, it was conducted on the Internet. In the questionnaire, a Likert scale of ten was used. The reason for this was that all the criteria to be analyzed already have high importance. If scale

of five were used, it would not be sufficient to stress the slight differences among criteria. In order to reach the people involved in consultancy, the survey was sent to the corporate mails of all the consulting firms in Turkey. It was also sent to all mail groups that are concerned with consulting business.

Eighty responses were returned. The answers given by the respondents to the question asking their comments about the study revealed that most of the respondents were quite happy that a study on consultancy was being conducted. They all mentioned the need of further studies in the field. Some even demanded more detailed and in-depth studies of consultancy business.

It should be stated that the respondents answering the survey were all Turkish consultants. Thus, the results obtained from the study reveals the case in Turkey and views of the Turkish consultants about the profession. However, these results may be used for comparison with other countries.

Statistical Analysis of the Findings

The following analysis of the data is conducted with a SPSS 11.0 software package. Table 1 illustrates the descriptive statistics for the four basic categories.

Table 1: Descriptive Statistics for Basic Categories

Category	N	Minimum	Maximum	Mean	Std. Deviation
Human Resources	80	5.25	10.00	9.0750	0.98276
Customer Relations	80	6.14	10.00	8.9089	0.87953
Processes and Methods	80	4.10	10.00	8.2962	1.07473
Competitiveness	80	2.67	10.00	7.8292	1.43983

According to the results of the survey, the Turkish consultants responded to the survey place the highest importance to the "human resources" category with an average of 9.0750. The second most important category was "customer relations" with an average of 8.9089. This is followed by the "processes and methods" category with an average of 8.2962. The respondents considered the "competitiveness" category least important with an average of 7.8292. The responses suggested that personal relations were still the most important point in deciding for the acceptability of projects in the Turkish Industry.

In Table 2, descriptive statistics for each criterion are illustrated. The respondents put more emphasis on the "trust relationship with clients" criterion than the others.

Table 2. Descriptive Statistics for Each Criterion

Criterion	N	Minimum	Maximum	Mean	Std. Deviation
Trust relationship with clients	80	7	10	9.55	0.778
Knowledge	80	5	10	9.25	1.185
Full support of top management	80	3	10	9.15	1.379
Definition and clear understanding of goals and reasons of the project	80	6	10	9.10	1.703
Skills	80	3	10	9.09	1.285
Continuous learning	80	4	10	9.07	1.376
People	80	5	10	9.05	1.211
What has changed for better	80	5	10	8.95	1.211
Did the consultant understand the company and its problems and come up with creative solutions	80	6	10	8.95	1.550
Efficiency	80	3	10	8.91	1.460
Obtaining answer to three main questions	80	4	10	8.91	1.193
Cooperation with clients in finding solutions	80	6	10	8.90	1.165
Is the organization moving forward	80	5	10	8.73	1.331
Future thinking	80	2	10	8.72	1.630
Strong image and reputation	80	1	10	8.70	1.664
Informing client regularly and frequently	80	5	10	8.70	1.344
Clear expression of capabilities	80	1	10	8.70	1.702
Customer-driven growth strategy	80	1	10	8.69	1.658
Consideration of client's willingness and ability	80	5	10	8.68	1.474
Tangible results and changes	80	5	10	8.62	1.335
Considering the implementation process as well as suggestions	80	5	10	8.50	1.765
Being among best in at least one service	80	1	10	8.48	1.961
Teaching fishing rather than giving fish	80	1	10	7.85	2.129
Innovation	80	3	10	7.78	1.882
Serving in shortest time possible	80	3	10	7.35	2.171
Incremental successes instead of one big solution	80	2	10	7.05	2.116
Diversification of services	80	1	10	6.31	2.416

It is observed that engagements and selection of the consulting firm to work with are strongly dependent on personal relations in the Turkish consulting industry. This fact resulted in rating the criterion "trust relationship with clients" for the first place with a significant difference.

Respondents placed the "knowledge" criterion at the second place with an average of 9.25. After this comes the "full support of top management" criterion with an average of 9.15. The reason for the "full support of top management" criterion being so high, - in the third place among the 31 criteria - may be pointed out as a result of most Turkish companies being family firms. It is a common practice in the family firms that every decision is made by the owner(s). The owner or the boss has the right to abandon the project if they believe it is necessary. Because the Turkish managers do not know how to work with or do not believe strongly in management consulting, leaving a project incomplete is a common practice for the Turkish consultants. This is probably the reason why the "full support of top management" criterion is placed in the third place.

The "definition and clear understanding of goals and reasons of the project" criterion is placed in the fourth place with an average of 9.1 and the "skills" criterion at the fifth with an average of 9.09. Because the "knowledge" criterion is placed at a significantly higher rank than the "skills" criterion, it may be concluded that the consulting projects in the Turkish Manufacturing Industry are generally based on knowledge rather than skills. Perhaps, it may be remarked that the consultancy projects are mostly "procedures projects."

In regard to the least important five criteria, the criterion considered as the least important one is the "diversification of services" criterion with an average of 6.31 that is followed by the "incremental successes instead of one big solution" criterion with an average of 7.05. The third place belongs to the "serving in shortest time possible" criterion with an average of 7.35, the fourth the "innovation" criterion with an average of 7.78 and the last one "teaching fishing rather than giving fish" with an average of 7.85. The reason why "diversification of services" received such a significantly low average may be the structure of the Turkish Consultancy Industry. Because the Turkish Manufacturing Industry is not so innovation oriented, only a few firms provide diverse services and most focus on specific tasks. The "innovation" criterion ranked as one of the least important criteria confirms that most of the consultancy work is "procedures projects."

CONCLUSION

This study is probably one of the first in the field of consultancy in Turkey. The aim of the study was to reveal the basic success criteria for management consulting operations. Because the topic is so untouched and wide, it has not been possible to

determine success criteria more in detail. However, we may say that it has been a useful and efficient study. The survey conducted in the Turkish Consulting Industry provided an analysis of the viewpoints the Turkish Industry and the Turkish Consultants.

As a conclusion, it may be remarked that this study aims to be the first step that will lead to further researches. The responses received from the consultants were quite satisfying, but the most important thing that this study revealed was the interest and desire for further studies relating to consultancy.

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Biography

Dr. Sitki Gozlu is a professor of production and operations management at Faculty of Management at Istanbul Technical University. He holds a B.S. in Chemical Engineering from Bogazici University (June 1969), a M.A. in Management from Istanbul University (June 1981), and a Ph.D. in Management Engineering from Istanbul Technical University (June 1986). He became Associate Professor in October 1990 and full Professor in December 1996. He served as the Department Head between September 1997 and September 2000 for three years. Dr. Sitki Gozlu worked as a researcher at Marmara Research Institute for two years, and in the private sector as a plant and technical service engineer for more than four years. He lectures on "Quality Assurance and Control" and "Management of Technology" at the undergraduate level, and "Production and Operations Management" (MBA) and "Total Quality Management" (MBA), "Manufacturing Systems Management" and "Project Management" at the graduate level. His research interests are in the areas of technology, productivity, quality, and project management. His works have been published in international and national journals and conference proceedings. He is a member of Turkish Chamber of Chemical Engineers, Production and Operations Management Society (U.S.A.), European Operations Management Association, International Management Development Association (U.S.A.), and American Society for Quality.

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The Dynamics of Capabilities in the Transition to Telecommunications Next Generation Networks

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Abstract

This paper examines the dynamics of capabilities in the transition to the so-called Next Generation Network (NGN), in the telecommunications industry. This transition is occurring in major incumbent fixed telecommunications operators like BT (British Telecom), France Telecom and Deutsche Telekom, among others, where the innovation gap seems to be more challenging compared to mobile operators and cable TV companies. We analyze the capabilities development of BT in the United Kingdom, using documentary and interview data. The main conclusion is that, during the transition, capabilities vary rapidly in intensity: at the very beginning, strategic capabilities influence the decision-making and define the transition, and then project capabilities are put in place to deploy the strategy, until functional capabilities take over and maintain the evolutionary path of the technology until a next major transition may occur.

Keywords: Telecommunications; Next Generation Network; Large Technical Systems; Complex Products and Systems; Capabilities.

INTRODUCTION

This paper is about how capabilities evolve in the transition to Next Generation Network (NGN) of incumbent fixed telecommunications operators. The context is represented by the network owned by incumbent fixed telecommunications operators

(e.g., BT (British Telecom), Deutsche Telekom and France Telecom), usually known as PSTN (Public Switched Telecommunications Network), which has more than 100 years of history and is based on the circuit-switched technology. This huge and traditional network is under transition, which consists of replacing the circuit-switched technology and adopting a new one, based on packet-switched technology. After some years of battle among packet switched technologies, mainly the ATM (Asynchronous Transfer Mode) and IP (Internet Protocol) and the advent of the public Internet, it seems clear now that the IP technology is a consensus in the market. This paper concentrates on the period of 1995 to 2005 of this transition. Major incumbent telecommunications operators around the world are deploying the so-called Next Generation Network (NGN), based on the IP technology.

By 2005, major incumbent fixed telecommunications operators have already announced plans to migrate to the Next Generation Network (NGN), an all-IP platform which enables them to deliver a whole range of new services, besides the voice-only services. A major announcement is the BT 21st Century Network (BT 21CN) in the UK, a £10 billion programme established to switch-off the PSTN and switch-on the all-IP NGN in five years.

Having the concepts of LTS (Large Technical Systems) and CoPS (Complex Products and Systems) as the background, this paper investigates capabilities development in the transition to NGN, using resource-based and strategic views to explain the capability evidences.

METHODOLOGY

The research was conducted through interviews and analysis of documents such as reports, newspaper articles and official Internet websites. The reports included annual reports of suppliers and incumbent service providers, and documents of regulators. The interviews were conducted with senior managers, managers and other practitioners of incumbent telecommunications service providers and suppliers, regulators, consultants and market research analysts.

The unit of analysis is a complex system: the telecommunications network in transition to NGN in the context of incumbent fixed telecommunications operators. The context of incumbent fixed telecommunication operators was chosen because it seems to be where the innovation gap is bigger. They come from a traditional and secular voice-only service and they are losing space to mobile and cable TV operators, which are able to provide more advanced and interactive services. Also the Internet is having a major impact on the fixed operators, regarding its network architecture and business models. The transition of BT was chosen because it seems to be, at the time of this research, the most influential and radical approach in the global telecommunications market.

LITERATURE REVIEW

This literature review is comprised of the concepts of Large Technical Systems (LTS), Complex Products and Systems (CoPS) and capabilities.

Large Technical Systems (LTS) and Complex Products and Systems (CoPS)

The aim of this paper is to examine the transition to NGN of telecommunications networks viewed as what Hughes (1983; 1987; 1992) calls Large Technical Systems (LTS), whose main components are Complex Products and Systems (CoPS), such as defined by Hobday (1998, p.690) as 'high cost, engineering intensive products, systems, networks and constructs'. In LTS, the unit of analysis is a complex system, defined as 'coherent structures comprised of interacting, interconnected components [ranging from] relatively simple machines to regional electricity supply networks' (Hughes 1983, p. ix). Davies (1996) argues that this definition is different from the concept of complex systems offered by Miller et al.(1995), where 'the unit of analysis is the product and the nature of its production: that is the supply of large, complex, customized, engineering-intensive products or systems, in which production is of "one-off" kind, usually on a project basis, to meet the requirements of individual customers' (Davies 1996, p. 1145-1146). Some related researches (Rycroft and Kash 1999; Prencipe 2000; Hardstone 2004) investigate the context of Complex Products and Systems (CoPS), as categorized by Hobday (1998), from the supplier perspective. Davies and Brady (2000) also approach the organisational capabilities in CoPS from the supplier perspective. Little attention is given to the user perspective. In fact, Prencipe, Davies and Hobday (2003, p.11) affirms that 'currently research barely scratches the surface of systems integration from the user perspective'. In this research, the incumbent telecommunications service providers are users of CoPS, and in the transition process they need to develop new capabilities to adopt CoPS, and at the same time, make old capabilities that are not useful anymore go away.

Complex systems have been studied by several authors (Miller, Hobday et al. 1995; Davies 1997; Hobday 1998; Rycroft and Kash 1999; Hobday, Rush et al. 2000). The category of Complex Products and Systems (CoPS) is used to distinguish from the mass production industries. Usually, they require a high variety of distinct knowledge bases, intense user and other supplier involvement, stretching the boundaries of the organisations involved in the production and delivery of CoPS.

Davies and Hobday (2005) show how capabilities evolve in the supply of CoPS. The transition to NGN is an opportunity to study capabilities development in the adoption of CoPS by incumbent telecommunication fixed operators.

Capabilities

In order to make the transition to NGN, incumbent fixed telecommunications operators need to make not only technological, but also organisational transitions.

Several organisational capabilities depicted in the literature are necessary for an operator to succeed in this transition. The concepts of core competence, core rigidity and routines emphasize the internal side of the firm, with low emphasis to the relationship with the environment. The dynamic capability approach started to consider the external environment more emphatically.

Prahalad and Hamel (1990) diffused the concept of core competence as a way to rethink the corporation. As firms diversified and grew in size and complexity, 'the diversified company became a large tree.[...] The root system that provides nourishment, sustenance, and stability is the core competence' (Prahalad and Hamel 1990, p. 82). They defined core competencies as 'collective learning in the organization especially how to coordinate diverse production skills and integrate multiple streams of technologies' (p. 82) and as 'communication, involvement, and a deep commitment to working across organizational boundaries' (p.82). It is interesting to note that these definitions of core competence refer to 'integrate' and 'work across organizational boundaries', which are characteristic of systems integration and project management activities. Most importantly, although the firms may have a huge and diversified portfolio of projects and business, they share a few core competencies (Prahalad and Hamel 1990).

When core competencies are too entrenched within the firm, they may create inertia to change and may be transformed into core rigidities, an expression used by Leonard-Barton (1992; 1995). As changes occur faster and more frequently, core rigidities become more salient and exposed. Core rigidity may not only be in technology, but in attitudes and actions that were successful in the past, but are not valid anymore or are counterproductive in the present but managers find it difficult to change. At times of transition, when old ways of doing things need to be abandoned or replaced, core rigidities may play a significant role.

Nelson and Winter (1982) proposed that 'the routinization of activity in an organization constitutes the most important form of storage of the organization´s specific operational knowledge'. More than twenty years after writing that, it is important to point out the issue of routines, as change is now a dominant topic, and it seems that routine and change are antagonistic. Even when dealing with projects as one-off activities, it is possible to have gains on 'economies of repetition', where learning from one bid/proposal can be used in others, and also routines used in one project can be replicated in others (Davies and Brady, 2000). The search of patterns and principles in the midst of apparent disordered situations is the challenge. At times of transition, where the old is abandoned and the new is adopted, routines within the firm seem to have a major transformation.

Teece and Pisano (1994) used the expression 'dynamic capabilities' to address the 'key role of strategic management in appropriately adapting, integrating, and re-configuring internal and external organizational skills, resources, and functional

competences toward changing environments' (p. 538). They use the strategic dimensions of the firm 'as organizational processes, its present position, and the paths available to it' (p. 541). Processes can be understood also as 'routines', as defined by Nelson and Winter (1982), including the learning and current practices within the firm. The position refers to the relationship with customer and suppliers and its internal conditions in terms of technology and intellectual property. Paths refer to the strategic alternatives which are available to the firm and which the firm is more attracted to (Teece and Pisano 1994).

It is important to notice that Teece and Pisano (1994) emphasize the strategic and functional capabilities within the firm and its ability to cope with changing environment. Davies and Hobday (2005) build upon resource-based theories of the firm (Penrose 1959; Nelson and Winter 1982; Teece and Pisano 1994) and highlight the project capabilities, along with strategic and functional capabilities, as shown in fig. 1, in order to survive and grow in rapidly changing technologies and markets.

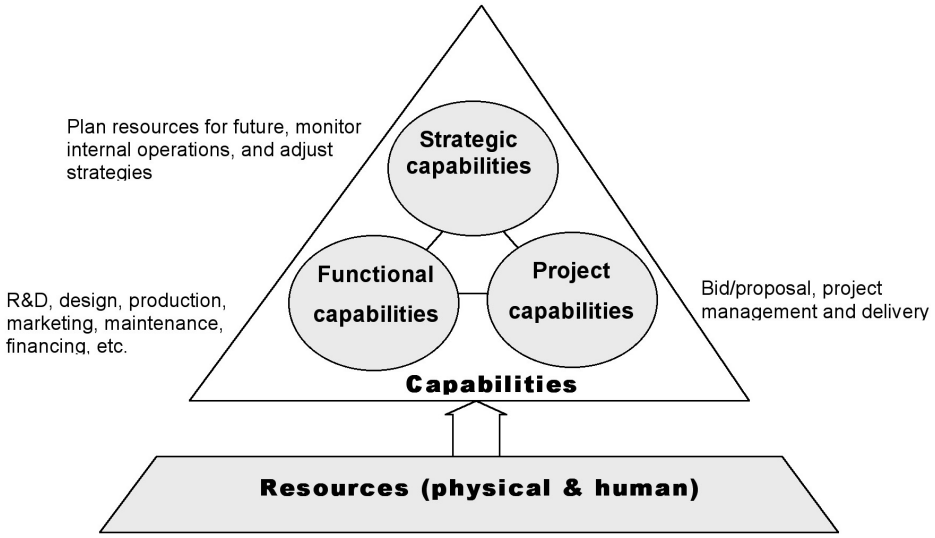

Fig. 1 – Resources and Organizational Capabilities Source: Davies and Hobday (2005).

The resource-based theories of the firm (Penrose 1959; Nelson and Winter 1982; Wernerfelt 1984; Teece and Pisano 1994; Teece, Pisano et al. 1997) provide a good explanation for the firms growth and competitive advantage when they are in periods of incremental innovation and accumulation of capabilities, where a major 'equilibrium state' is identified. However, it provides less insight in situations of transitions from one technology to another, where the knowledge base is being changed and not only the firm but all the actors of the innovation value chain are being repositioned.

Taking into account the Penrose (1959) resource-based view of the firm, Davies and Hobday (2005) argue that this approach ignored the project as an organisational capability and source of competitive advantage. The project is largely recognised nowadays as the most appropriate organisational form to address change and to conduct business. It seems that this is occurring because the customer-focused or customer-centric approach is now dominant in the dynamic market and is a necessity in order to remain competitive. Then, project capability has acquired momentum in daily business.

BT CAPABILITIES IN THE TRANSITION TO NGN

BT was the first major incumbent fixed telecommunications operator to announce the transition to NGN and establish a deadline to switch-off the PSTN. BT created a project called 21st Century Network or 21CN to make this transition. At the time of the project announcement in 2004 about 300 firms expressed their interest in supplying to BT. In 2005, BT announced the eight preferred suppliers for the 21CN: Siemens, Alcatel, Cisco, Fujitsu, Huawei, Ciena, Ericsson and Lucent.

BT decided to divide the network into five parts and chose at least 2 suppliers for each part, except the I-node, which is the intelligence of the network, granted only to Ericsson. Although the tendency would be to work with one prime contractor acting as the system integrator, no single vendor would take the risk to supply the whole network. So, a considerable work of project management and systems integration needs to be done within BT.

The BT 21CN represents, in terms of services, a transition from commodity (or capacity) to capability. The PSTN network is largely known for its robustness and provision of voice-only services. And it has around 100 years of history. The fact is that voice-only services are becoming a commodity. And if in the past the focus of the network was in provisioning capacity to a large number of users to communicate with each other effectively and reliably through voice-only services, the transition represents a shift from capacity provision to the provision of capabilities: flexible services which conforms to customers needs at a specific moment. With 21CN, it seems that BT intends to be the leader of a movement, not the commander of a structure.

The success of 21CN depends not only on BT´s capability to build the convergent network but also on what Mansell and Steinmueller (2000) call 'understanding the factors influencing the rate of market development' (p. 103) and how to address it: once the network is built, how to make the customers adopt the new services and how BT and its ecosystem generate new services for the market.

The core competence of BT seems to remain the ability to build and maintain networks and provide services, as BT has the vision of becoming a 'Global Networked IT Services Company'. In other words, the core competence is and will continue to be

focused on the network, not on content. With convergence, meaning here industry convergence of content providers, telecommunications companies and IT firms, there is a speculation that BT could be also a content provider, becoming a competitor of firms like Sky or BBC, for example. However, BT seems not be going in that direction. At least for BT, the transition and the phenomenon of convergence is not changing its core capability. At this point, the phenomenon of convergence does not seem to be if one company will be a direct competitor of another company in another industry, like BT becoming a competitor of Sky, but how both companies will cooperate together to address the market, and prepare its infrastructure to do so.

The period of transition offers a space to 'core rigidities' to flourish, as new processes and institutional changes are being developed and old processes are being dismissed or reformulated. Core rigidity involves not only the change of internal processes per se, but also the people involved. The transition to NGN involves not only technological, but also cultural change within BT.

Routines, understood as processes inside companies, are certainly changed during a major transition like this. One interviewee said that the real challenge is not the technology itself, but what takes time in the transition is to change the internal processes set for PSTN which are being reinforced for many years.

In BT transition to NGN, routines are being changed due to technological change, from circuit-switched PSTN base to packet-switched IP (Internet Protocol) base. These routines are related to the operation of the network. However, the transformation of the network implies in modifying also current relationship with customers and the provision of services. Thus, routines are not only changing for internal operations, but also to address the interface with customers and third party firms which may use BT infrastructure to provide new services.

As long as old routines are dismissed, new routines are created. And these routines are more related to the platform for creation of new services from third parties and from BT itself. Many new routines are being created or redesigned in order to address the creation of new services and the more intense relationship with partners (or ecosystem). One example is the common capabilities approach (Levy 2005), where BT is identifying common elemental building blocks to be used in a variety of services, thus reducing time to market and cost to develop new services.

The objective of the BT 21CN is to create a common platform to address the changing needs of customers. Customers can be end customers or other firms which use BT network to provide services. From this perspective, the transition to NGN, and the 21CN in particular, increases BT dynamic capabilities to address the changing communications market, enabling BT to respond faster and more flexibly to demands from customers. More external relationships and the capability to establish and maintain those relationships seem to be more and more important as long as 21CN evolves. This is a situation different from previous technological changes suffered by

the incumbent fixed telecommunication operators, more focused on expanding and improving their network capacity.

Taking into account the framework of strategic, functional and project capabilities proposed by Davies and Hobday (2005) and transporting into BT´s context, these three capabilities are very strongly present in the transition to NGN and it seems that they have different intensities over time. First, the decision making of the transition needs a strong strategic capability. The decision to invest £ 10 billion in a relatively short period of time (about 5 years) was certainly not an easy one. Coincidentally, the announcement of the BT 21CN was made after some few years the top management (CEO and CTO) of BT was changed, and top managers outside BT took over. This certainly had an impact on BT´s top management dominant logic and influenced the decision to approve the 21CN project.

The project capability is formalized through the establishment of the BT 21CN Programme. Davies and Hobday (2005, p. 77) point out the project as the basic unit for a firm to survive, grow and achieve its strategic objectives. As revenues from its traditional services are declining, BT is addressing, through 21CN, its strategic objectives for survival and growth: keep a relentless focus on improving customer satisfaction, put broadband at the heart of BT, create mobility services and solutions, transform the network for the twenty-first century, achieve competitive advantage through cost leadership, lead the world in network-centric ICT solutions, reinvent the traditional business, motivate people and live the BT values (BT 2005b). During the transition, 'BT needs more than ever some world-class project management skills, followed closely by some world-class communication skills' (Communications News 2005). The 21CN certainly moves BT into a new technology base, however it does not seem to move to a new market base in its domestic market, as major customers being addressed are still the mainstream customers. The way to approach customers changes significantly though. BT 21CN makes it possible for BT to expand its market base globally from a common and robust network.

Along the transition, capabilities are transferred to functional departments, which will carry out the daily activities of maintaining and upgrading the network, following an evolutionary way. Of course, projects of a smaller scale may be set up to address specific problems, but not at the same scale and scope of 21CN. The lean operator which is expected to emerge after the end of the BT 21CN project is due to a major optimization of BT´s functional capabilities, where is expected cost reductions in operational expenditures of about £ 1 billion from 2008/2009.

In summary, the strategic, project and functional capabilities interact during the transition, but they are required with different intensities over time: at the beginning of the transition, strategic capabilities need to be strong in order to decide to make the transition and set the goals and principles of the transition strategy; once decided to make the transition, it is necessary to implement the strategy, and

that is where project capabilities become more important or 'intense' (BT established the BT 21CN Project for the transition); at the final stages of the transition project, functional capabilities become again more intense, and new capabilities are transferred to existing and new functional activities.

CONCLUSIONS

In this paper, we examined various concepts of capability and its application to the recent transition to Next Generation Networks (NGN) being undertaken by incumbent fixed telecommunications operators. Having the concepts of Large Technical Systems (LTS) and CoPS (Complex Products and Systems) as the background context, we used the concepts of the resource-based view to analyze the complex system in transition, which is an interesting unit of analysis, as major studies concentrate on the evolutionary period between such transitions.

For the transition to occur, it is necessary to overcome the innovation level which the decision makers accept and the level of risk and uncertainty which the organisation tolerates. The transition represents the battle between the innovative and the conservative organisations.

The main conclusion is that, during the transition, capabilities within the incumbent telecommunication operator vary in intensity: at the very beginning, strategic capabilities influence the decision-making and define the transition, then project capabilities are put in place to deploy the strategy, until functional capabilities take over and maintain the evolutionary path of the technology until a next major transition may occur.

The main implication of this technological transition is building a 'flexible factory of services', where the network is able to adapt to the customer and not the opposite. The most competitive service providers will be those able to provide flexibility to adapt to changing customers needs and retain those customers. This flexibility involves the combination and recombination of voice, data and video to satisfy customer needs at the right time.

Of course, there are limitations in this research. Analyzing just the case of BT (British Telecom), for example, is not possible to make more generalizations. Initial industry analysis indicates that the transition to NGN is undertaken in very different ways by the various incumbent fixed telecommunications operators. However, the innovation principles seem to be the same. Comparisons with other incumbent fixed telecommunications operators, like Deutsche Telekom and France Telecom would be helpful.

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