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AN EXPERT DIAGNOSIS SYSTEM FOR THE BENCHMARKING OF SMEs' PERFORMANCE

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Abstract: Although benchmarking has proven to be valuable for large businesses and organizations for quite sometime, up until recently, serious doubts existed as to its usefulness for smaller businesses. In this paper, we present the PDG[®], a benchmarking system meant to evaluate SMEs from an external perspective in order to produce a diagnosis of their performance and potential, complemented with relevant recommendations. Our research results show that benchmarking allows SMEs to improve their operational performance thus confirming the usefulness of benchmarking. These results also confirm the value of the recommendations included in the PDG[®] report concerning short-term actions to be undertaken to modify management practices. We think the PDG[®] system proves that if the benchmarking approach is tailored to SMEs' characteristics, an adequate tool can be devised and used to help SMEs increase their performance.

Keywords: Benchmarking, Performance, Expert Systems.

1. BENCHMARKING FOR SMEs

The importance of evaluating performance is obvious for business enterprises in general, and for SMEs in particular. Facing increased competitive pressure due to globalization, as well as increased quality and service requirements from their customers, small and medium-sized manufacturers must increase their productivity and their competitiveness in order to survive and prosper, even if they do not intend to become "world class" enterprises. One approach to the evaluation of a SME's situation is to compare the firm's business practices and performance with those of a group of similar firms, that is, to "benchmark" the organization. As management challenges have increased in complexity, benchmarking has become a strategic tool for organizations of all sizes.

Whatever the type of benchmarking used, internal, competitive or generic, it is deemed to be a strategic tool that allows the firm to identify possible sources of improvement in order to increase its performance and its competitiveness

(Haughton *et al.*, 1999). The benefits of benchmarking are being more and more recognized, less so in SMEs however where its use still remains relatively sparse (Prabhu *et al.*, 2000). In this last regard, Monkhouse (1995) states that smaller firms would have a lot to gain by this activity, notably in breaking the entrepreneurs' "isolation" by providing them with information on what is being done by other firms similar to their own. This author notes however that it is very important to first convince entrepreneurs of the relevance and usefulness of such a management tool, thus justifying the significant amount of time spent by themselves and their key employees on benchmarking activities.

Our answer to this challenge of the utmost importance for SMEs was to design, develop and test an advanced computerized benchmarking tool. This tool, the PDG[®] (Performance, Development, Growth) system, constitutes the foundation of our work on SMEs benchmarking, a domain in which the LaRePE lab has been involved for many years. This is what we discuss in this paper, taking as the basis of our presentation the PDG[®] system (www.pdg-sme.ca).

2. THE PDG[®] BENCHMARKING SYSTEM: A BIRD'S EYE VIEW

The current version of the PDG[®] benchmarking system is the result of a long and demanding development process, a project that has been going on for more than 6 years and has so far necessitated a budget of more than 2 million Canadian dollars from multiple funding sources. Many people were involved, all of them in various specialization fields (i.e. management, marketing, accounting, finance, human resources, engineering, innovation, information technology, etc.): researchers, graduate students, research professionals and, of course, SME entrepreneurs.

The goal of the PDG[®] system is to *evaluate a SME, from an external perspective and on a comparative basis, in order to produce a diagnosis of its performance and potential, complemented with relevant recommendations*. Right from the beginning, the project evolved around the concept of a questionnaire that would be used to collect relevant information items on the SME to be evaluated. Data extracted from the questionnaire is computerized and fed into a complex benchmarking system that carries out the evaluation. The latter is performed in approximately 3 minutes by contrasting a particular SME with an appropriate group of SMEs for which we have already collected relevant data. The PDG[®]'s output, which we call the PDG[®] *report*, or report in Figure 1 below,

is a detailed report in which 28 management practices (concerning human resources management, production systems and organization, market development activities, accounting, finance and control tools, effectiveness and vulnerability), 20 results indicators and 22 general information items are evaluated, leading to 14 recommendations on short term actions the evaluated SME could undertake to improve its overall performance. The PDG[®] system is fully implemented and the actual version has been in production for 2 years. So far, we have produced more than 600 reports and accumulated in the PDG[®]'s database the evaluation results of 400 different manufacturing SMEs.

Figure 1 below shows the PDG[®] as a black box system, connected to an Oracle database that collects all the relevant data for benchmarking purposes. A team of multidisciplinary human experts constantly monitors the PDG[®] reports in order to ensure the evaluation is accurate and the recommendations are relevant. This validation phase, which always takes place before the report is sent out to the evaluated SME, is an opportunity to make further improvements to the PDG[®] system, whenever appropriate. It is also a valuable means for the human experts to update their own expertise on SMEs. Figure 1 also shows that an intermediary partner is part of the process in order to guarantee confidentiality: nobody in our lab knows to what companies the data are associated.

Fig. 1. The PDG[®] system: evaluation of SMEs, from an external perspective and on a comparative basis, in order to produce a diagnosis of their performance and potential.

A good deal of multi-domain expertise and informal knowledge engineering was invested into the design of the PDG[®]'s extended questionnaire, as well as into the benchmarking system. In fact, at the early stage of the project, it was even hoped that an expert-system approach

would apply naturally to the task we were facing—a prototype expert system was developed for a subset of the PDG[®] dealing only with human resources. However, reality turned out to be much more difficult than anticipated. In particular, the knowledge acquisition and knowledge modelling phases (Turban & Aronson, 2001;

Sierra-Alonso, 2000) were very demanding, especially in the context of a multidisciplinary domain such as that of SME benchmarking.

The current version of the PDG[®] system, although not implemented with artificial intelligence techniques, e.g. knowledge base of rules and facts, inference engine, etc. (see, e.g., Santos *et al.* 2002), qualifies as a “black-box” expert system. The expertise hidden in the PDG[®] system comes from human experts that have identified the appropriate contents, selected relevant information, associated adequate relative weights to evaluation elements, and prepared suitable recommendations for the evaluated SME. The knowledge, information and algorithms it uses allow it to produce outputs that only a human expert, or in fact several human experts in different domains, would be able to produce in terms of diagnosis quality, including recommendations. Over 90% of the reports produced by the PDG[®] system need no modification whatsoever before being returned to the evaluated SME. These reports contain mostly coloured diagrams and simple explanations that are formulated in plain

English (or French) so that SME entrepreneurs can easily understand and interpret them.

3. TAKING A CLOSER LOOK AT THE PDG[®]'s MAIN COMPONENTS

If we look at the PDG[®] from a systemic viewpoint, as illustrated below in Figure 2, we see that:

- Input consists of a broad-coverage questionnaire filled by the SME, their financial statements, including the accompanying notes, of the last 5 years;
- Processing is performed by the expert diagnosis system;
- Output consists of a detailed benchmarking evaluation of the SME's performance, plus recommendations.

In this section, we will take a look at these three main components in order to better understand the PDG[®] system and how it works.

Fig. 2. A simplified view of the PDG[®] system and its main components: from a broad-coverage questionnaire and financial statements to a detailed benchmarking evaluation and associated recommendations.

3.1 The PDG[®]'s Input: the SME's Data

The questionnaire on which is collected the data from the manufacturing SME to be evaluated is broad although not deeply specialized in any of the business' functions. It consists of 19 pages (plus a one-page appendix of term definitions) organized in these main sections:

- An indication of the SME's preference as to what *reference group* it wishes to be compared to. This information is crucial for benchmarking purposes. It is our experience that SMEs often have a hard time identifying their reference group, especially the first time around. This is one area where human expertise is needed: an expert of our lab must approve the group selection before proceeding to the evaluation itself—see the beginning of section 3.2
- A section to be filled by the business *owner-manager*: it includes questions about the owner's background, the existence of a board of directors, the strategy regarding new technologies, the strategy on market development, the usual sources of information on a dozen of subjects, the existence of a designated person in charge in various services or departments, an opinion on the firm's positioning relative to its competitors, a forecast on the firm's financial situation, and so on.
- A section to be filled by the *human resources manager*: it includes questions about the number of employees in various categories, employee training, employee evaluation, sharing of information in the organization, a forecast on the evolution of several employee categories, and so on.
- A section to be filled by the *controller or the general manager*: it includes questions about the enterprise's ownership, its main products or services, the geographical sales distribution, collaborations or alliances with other organizations, the value of production equipment, research and development, the importance of sales on credit, dependence on principal clients and suppliers, accounting and financial tools, information technologies, credit, interest rate, and so on.
- A section to be filled by the *production manager*: it includes questions about the nature of the enterprise's manufacturing operations, the usage of equipment over the year, subcontracting, certification, standards, continuous improvement ac-

tivities, quality, safety, use and proficiency in the use of various equipments and technologies, integration of production systems, control of operating costs, and so on.

Once all the data on a questionnaire, plus the complete financial statements of the last 5 years, have been manually verified, they are typed in via a software dedicated to this task and will finally end up in the PDG[®]'s database, ready for benchmarking. It is worth mentioning that the questionnaire's data complexity and diversity (i.e. qualitative, quantitative, historical, conjectural, perceptual, etc.) must be matched by the expert diagnosis processor that must contain all the required information and encoded knowledge to correctly perform the evaluation.

3.2 The PDG[®]'s Central Processing: Expert Diagnostic

The heart of the expert diagnosis system can be best described in relation to the report generator component, which acts as the main program. The 8 main steps of processing are:

1. The reference group is created according to a number of criteria usually after several iterations. It is sometimes necessary to create a few tentative reference groups in order to select the most appropriate one, thus ensuring the statistical validity of the benchmarking results, while preserving confidentiality of all SMEs. This processing takes place within the Oracle database.
2. A number of statistical computations (averages, medians, distributions) related to the reference group are performed within the SAS statistical package, after data from the Oracle database has been fetched.

Starting from here, the remaining processing is essentially performed from a Microsoft Excel application:

3. Statistical data is passed from SAS to Excel via an ODBC connection.
4. A bunch of automatic, numerical Excel computations take place at this stage in order to define the relative positioning of the evaluated SME to its reference group. This relative positioning will then be used to define the appropriate graphical representations (including colours), as well as related comments and recommendations.
5. Graphics and various representations associated with the numerical values just computed are then produced.

6. Textual comments on practices and results are computed, in correlation with the computations completed in the previous steps.
7. An evaluation summary, to appear on the report's first page, is produced. For each of the seven main business functions, it presents a synoptic bar diagram showing the evaluated SME's relative position, plus two recommendations as to what actions should be considered in the next few years.
8. The actual PDG[®] output report, containing the benchmarking results, is then produced and saved on disk. The report is displayed on the screen by the Excel application.

Step 6 deserves further explanations. In fact, why bother with textual comments to be added to the already abundant information present in the report? The main goal of the PDG[®] report is to guide entrepreneurs in the identification of potential sources of improvement in their business' performance. It turns out that the average entrepreneur cannot easily grasp all the information involved in such a report based solely on graphical representations (e.g. charts). This information is thus analysed by the PDG[®] system and textual comments on practices and results are automatically produced to facilitate the entrepreneur's interpretation task when reading the report.

The actual mechanisms used to automatically produce these textual comments are a bit tricky. In brief, they are similar to early AI techniques devised for natural language processing based on templates. A prototypical comment contains fixed and variable segments. The latter are determined according to the specific numerical values computed for the evaluated SME (during previous steps). Full computational detail on how the PDG[®] system produces its results is clearly beyond the scope of the present paper.

3.3 The PDG[®]'s Output: Benchmarking Results and Recommendations

The diagnosis produced by the PDG[®] system through benchmarking is presented in an easy-to-read report that uses mostly graphics, coloured (colours translates into shades of grey here) diagrams and charts, and numerical results—typical SME entrepreneurs are not fond of long textual reports. See the top right corner of Figure 2 for the report's general appearance.

The report consists of 10 pages. The first page presents a summary of the evaluated SME along the main enterprise functions, using a

cursor-based graphical representation. The report's next two pages present a summary of the SME's reference group characteristics, all illustrated with coloured pie charts and bar charts. Then a one-page summary on each of the following topic is presented: human resources, production systems, production management, sales/marketing, management and control, effectiveness, and vulnerability. All are illustrated with graphical representations of the kind shown in Figure 3 below. On each of these pages appear brief textual comments and recommendations, when appropriate, on the SME's practices and results. Here is an example comment on practice evaluation of human resources (the variable segment is in *italics*): "Your human resources management practices are *generally more advanced* than those of your reference group. You could improve your performance, *in particular by implementing participative management to involve employees in the growth of the business.*" And here is an example comment on human resources results (the variable segment is in *italics*): "Your overall effectiveness at managing human resources is *comparable* to that of your reference group. *You should pay attention to why certain managerial jobs have a high rate of voluntary departure, with the objective of lowering hiring and training costs.*"

Fig. 3. Graphical representations make benchmarking results easy to understand by always positioning the evaluated SME relative to its reference group.

One final remark on the PDG[®] report. Before it is sent to the evaluated SME, at least one expert from our lab validates its contents. This expert must complete the comments appearing on the first page by selecting the most appropriate comments from a precompiled list of potentially

relevant candidates. These textual comments must be determined from a global perspective in which the human expert will consider interrelationships between various aspects that appear independently in the report.

4. EVALUATING THE USEFULNESS OF THE SYSTEM'S RECOMMENDATIONS

A study was made of 307 Canadian manufacturing SMEs that have used the PDG[®] report, including 49 that have done so more than once. The aim of that study was to show the importance of benchmarking for manufacturing SMEs in the new business environment and to assess the utility of the PDG[®] report (and, implicitly, of the PDG[®] system) to help businesses to identify management practices that needed to be adjusted. Our results show that this activity allows these organisations to improve their operational performance confirming the usefulness of benchmarking but also, the value of the recommendations included in the PDG[®] report concerning short-term actions to be undertaken to modify management practices (St-Pierre, Raymond & Andriambeloson, 2002). Although benchmarking has proven to be valuable for large businesses and organizations for quite sometime, up until recently, serious doubts existed as to its usefulness for smaller businesses. We think the PDG[®] proves that if the benchmarking approach is tailored to SMEs' characteristics, an adequate tool can be devised and used to help SMEs increase their performance. Benchmarking allows entrepreneurs to break the isolation in which they may be caught by comparing and positioning their SME to others (Monkhouse, 1995).

5. CURRENT STATE AND FUTURE DEVELOPMENTS

The current version of the PDG[®] system is fully functional and operates on an Oracle database. It also uses the SAS statistics package, plus Microsoft Excel for various calculations and the generation of the final output report. Up until now, SMEs evaluated with the PDG[®] were mostly manufacturing enterprises from the province of Quebec (Canada). Other SMEs are from the province of Ontario (Canada) and the USA. Recently, a deal was signed with a French businesspersons group for the production of 100 PDG[®] reports per year. Due to important differences between Europe and North America in the presentation of financial information, not mentioning cultural aspects that may have an impact on certain elements, this agreement will

necessitate some adjustments to the PDG[®] production system.

As far as future developments are concerned, we are conducting an in-depth revision of the current PDG[®] system in order to reengineer the system's architecture from a data mining perspective. We also need to migrate to newer and more efficient Web-based technologies (Java and Oracle), thus allowing various improvements and making a further step toward a fully interactive online version of the PDG[®] system. These developments are also made in response to international potential partners who want to have online access to the PDG[®] benchmarking system, especially its report, thus reducing the risks of losing strategic and financial information that must be sent by non-electronic mail otherwise.

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