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A STRUCTURAL ANALYSIS OF BUSINESS PROCESSES FOR MEASURING THE IMPACT OF REENGINEERING

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Abstract. Most efforts in business process reengineering to date are motivated by potential improvement in performance measures such as costs, quality of products or services, and cycle time for their delivery. While obviously important, these factors do not necessarily reflect any intrinsic improvement in how work is organized. This paper presents an approach to the structural analysis of business processes. The goal is to capture an inherent degree of synchronization of the various interdependent activities involved. This way, the process before and after reengineering, or alternative designs, can be compared without arbitrary scaling effects introduced by nonstructural variables. Our methodology for modeling and analysis incorporates established techniques in fuzzy logic and systems. Its application to a well-known example is used as illustration.

Key words: business process reengineering, structural analysis of business processes, fuzzy logic and systems.

1. Introduction. There is a big distinction between doing a job and getting work done. They mean the same only if the job is designed perfectly to accomplish the intended work. As business activities become more complex, such seamless match-ups can be a rare phenomenon. For one thing, a job description is routine-oriented and habit forming. It is not meant to change constantly or drastically. Whereas, the work required depends on external factors such as customer needs. In the era of mass production, a stable environment was essential to exploit economies of scale. This brought on job standardization as well as the mind-boggling growth in bureaucracy. As a result, many workers follow so-called "standard operating procedures" throughout a career without any appreciation of a bigger picture – how value is created for the customer and how this work gets done.

With better-informed and more value-conscious customers having access to a global market, the scenario is quickly changing (Ho, 1994). No enterprise can get by, at least not for much longer, without a comprehensive rationalization of its work processes. The critical question to ask about any job is whether it is value added, or red tape. With pressure from mounting competition and more sophisticated customer demands, business organizations are rethinking work. Approaches vary: from continuous and incremental improvement espoused in Total Quality Management (TQM) to radical restructuring manifested in full-blooded renditions of Business Process Reengineering (BPR) (Hammer and Champy, 1993). While case studies abound in both the business press and professional journals (Allen and Nafius, 1993; Cole *et al.*, 1993; Housel and Morris, 1993) failure rates have been high – as much as 50–70% by some estimates (Cafasso, 1993).

Critics are also skeptical of the true purpose of many reengineering efforts. They see it as short-term, reactive attempts to cut costs and downsize business operations to improve on immediate return on investment. As top executives are often evaluated primarily by quarterly earnings, it is not difficult to cast their actions in such a light. Investors seem to be likewise motivated. This may explain why after any announcement of a massive layoff by a company, its stock price almost invariably rises. However, it is often impossible to judge whether such restructuring is a passive move or a truly visionary attempt to revitalize a business.

Since bottom-line results depend on so many accounting and financial variables, not to mention uncertainties in the external environment, intrinsic improvements in the reengineering of a work process are often lost in the shuffle. What have been lacking are structural measures of the effectiveness of alternative designs for the process. As an analogy, consider an engine that runs on gasoline, and one that runs on natural gas. The economic efficiencies of operating these engines depend on the costs of the different fuels. The winner today may be the loser tomorrow if there is enough of a price change. However, the physical efficiencies in converting given heat content of the fuels to usable power are inherent in the designs.

While acknowledging the importance of bottom-line measures, we content that it will be very useful to be able to capture some structural properties of a process. This is the purpose of the research presented in this paper. We outline a modeling framework and an approach to a structural analysis of business processes that lead to a quantifiable measure of their intrinsic efficiency. A well-known example in the literature is used to illustrate the method.

2. The modeling framework. A business (or work) process is viewed as a network of interdependent activities. Since the activities involve people, any analysis would not be exact without considering personal incentives, motivation, and intent. However, in order to arrive at tractable models, we start with the following premises.

- A process has definite boundaries.
- A process has actors.
- A process consists of interrelated subprocesses.
- Subprocesses are characterized by attributes.
- Many of the attributes and interrelationships are not amenable to precise quantification.
- Imprecise or ambiguous descriptors of subprocesses can be captured by existing methodology in fuzzy logic and systems.

The underlying fuzziness of process attributes and interrelationships can be illustrated with some examples.

- When a customer calls to ask for *immediate* delivery, assign a priority to the order if the customer is *very important*.
- When a client requests a *substantial increase* of the credit line, make a decision based on his or her *creditworthiness*.
- If a task is *information intensive*, design an information system for it.

While arbitrary lines can be drawn to delineate any of the highlighted notions, there is no escaping that they are fundamentally imprecise. Fuzzy logic, with its short yet tortuous history, has been shown to be useful in many innovative products and decision-making scenarios (Dutta, 1993; Kosko, 1993; Zadeh, 1989; Zimmermann, 1991). We propose to apply established methodology to handle various attributes in the modeling framework. These include:

a) subprocess attributes – operational intensity, informational intensity;
b) linkage attributes – operational dependence, informational dependence, time-lag factor, synchronization factor;
c) actor attributes – operational ability, informational ability, decision-making ability;
d) macro-structure attributes – knowledge barrier, control barrier.

In the present work, we focus only on the linkage attributes. It should be remarked that an alternative framework would be the traditional Bayesian statistical decision theory using "subjective probabilities." However, as this approach addresses uncertainty and judgmental ambiguity over well-defined outcomes, we chose to apply fuzzy logic which models the ill-defined attributes of business processes more appropriately.

3. Linkage attributes. Three attributes are identified to model the interrelationship among activities within a business process.

i) *Operational dependence*:

This reflects the dependence of one subprocess on the completion of another, which may be due to the flow of either a physical entity or a piece of information. If a subprocess cannot be started before another subprocess is completely finished and some resources are passed along, the dependence is total. Otherwise the dependence is partial. Operational dependence can be on both upstream and downstream subprocesses. The latter occurs in feedback or corrective loops.

We treat operational dependence as a fuzzy attribute expressed as a fuzzy variable. To describe the dependence of subprocess-j on subprocess-i, we start with a base variable denoted by OpDep(i, j). This is either a) the percentage of subprocess-j that has to wait till the successful completion of subprocess-i, or b) the percentage of subprocess-j that can be accomplished only after the successful completion of subprocess-i. While the last two definitions are equivalent, they actually apply to slightly different situations depending on the operations being modeled.

Each value between 0% and 100% is then mapped into one or more of the following fuzzy sets: "A little", "Small", "Medium", "Large", "Very large". Each set is defined by a fuzzy membership function of the domain [0%, 100%] using input from the subprocess owner. In principle, it can have any shape and form.

The procedure to establish OpDep(i, j) can be described as follows.

Can subprocess-j start before subprocess-i is finished?

If not, then OpDep(i, j) = 100%;

else, can subprocess-j be always finished before subprocess-i is over?

If so, there can only be a resource dependency, and OpDep(i,j) =0%;

else, there is both a partial resource and time dependency of subprocess-j on subprocess-i. OpDep(i, j) is set to be either

the % of subprocess-j that has to wait until the successful completion of subprocess-i; or

the % of subprocess-j that can be accomplished only after the completion of subprocess-i as the case may be.

ii) *Time lag factor*:

This accounts for any non value-adding time between two interdependent subprocesses. It can be due to time required in the transfer of resource and information, local queues and congestions within one subprocess, or breakdowns occurring in any part of the entire process. We express this factor as a fuzzy variable denoted by TimeLag(i, j). It is defined as the non value-adding time from the finish of subprocess-i to the start of subprocess-j, attributed to subprocess-i. The base domain of TimeLage is the time scale. Each value is then mapped into one or more of the fuzzy sets: "Good", "Acceptable", "Undesirable", "Unacceptable", again using input from the process owner. Note that for each pair of subprocesses, the base domain (time scale) can be different. For example, some many be in terms of seconds, others in minutes or hours, etc.

iii) *Synchronization factor*:

Synchronization means agreement in time or simultaneity of events. The events of primary interest in our context are the starting times of subprocesses. If all the subprocesses can start simultaneously, then the process synchronization, as well as any pairwise synchronization among subprocesses can be considered to be perfect. In this extreme case, the turnaround time for the entire process is determined simply by the duration of the longest subprocess. The other extreme case is when all the subprocesses are sequential.

In practice, business processes are likely to lie somewhere between these extremes. Loosely speaking, we can consider a highly synchronized process to be efficient provided that the subprocesses themselves are also efficient.

The degree of synchronization between subprocess-i and subprocess-j is expressed as a fuzzy variable Syn(i,j), which takes on values from the set "A Little", "Small", "Medium", "High", "Very High". The base domain for "degree" is taken to be [0, 100]. Syn(i,j) is a function of the other attribute variables OpDep(i,j) and TimeLag(i,j). The relationship among these variables are given by fuzzy inference rules (Zadeh, 1989), the details of which are omitted here. By defuzzifying Syn(i,j), we obtain a measure (Syn) of pairwise synchronization between subprocesses. A Syn value of 100 indicates perfect synchronization. We define an overall synchronization index (SynInd) for the process to be the Euclidian norm of the matrix of defuzzified Syn(i,j) coefficients.

4. A structural analysis of business processes. The procedures for mapping the subprocess activities and their linkages, the determination of the fuzzy attributes described above, and the computation of a synchronization index comprise a structural analysis of a given business process. A flow chart illustrates the steps in Fig. 1.

As a conceptual outline, the detail description of each step, as developed in Shrivastava (1995) is omitted here. However, we should point out certain important features.

- In the process graph, activities are associated with the nodes, and the entity flows with the arcs.
- In the analysis, we have provisions to consider both direct and indirect linkages. The reason to include indirect links is to capture explicitly the aggregate behavior of the process. This may be especially informative when comparing various options in process reengineering. By examining only direct links, the analysis is simplified with perhaps an opportunity cost of incomplete information.
- The impact analysis in Step 2 investigates the usefulness of indirect linkage for the given process. In a process graph that is highly connected, or that has many feedback/corrective loops, almost every subprocess would appear to be dependent on all others. However, typically only a small number of indirect links may have significant impact. This step identifies all valid indirect linkages among subprocesses.
- Matrices for operational dependence and time lags are developed from which the synchronization index is derived using established inference techniques in fuzzy logic.

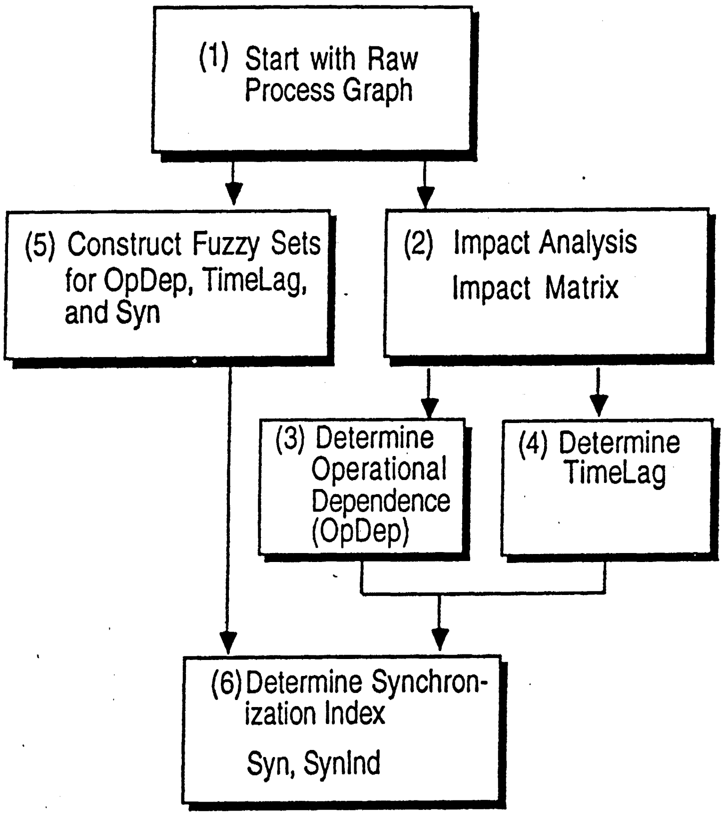

Fig. 1. Flow chart for structural analysis of a business process.

5. The Ford Motor Company example To illustrate our approach to a structural analysis of business processes, we use a well-known example in the literature (Hammer and Champy, 1993; Schnitt, 1993). The case involves the material acquisition process of the Ford Motor Company. It has been reported that Ford achieved dramatic improvement by reengineering the process. We applied our method to develop a synchronization index for the process before and after reengineering.

In the "before" scenario, the Accounts Payable (AP) function of the company collected purchase orders, material receipts, and vendor invoices. After matching information on the three kinds of forms, it cuts a check to the ven-

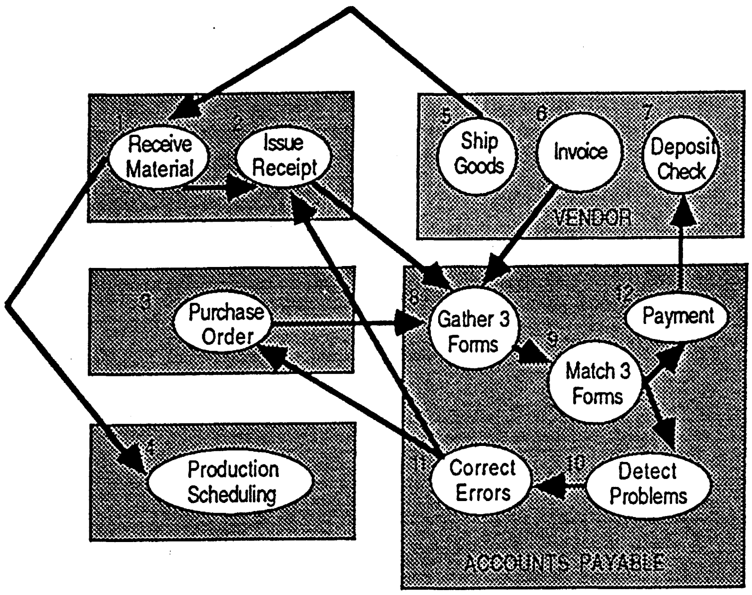

Fig. 2. FORD process: before reengineering.

dor. (See Fig. 2.) Mismatches triggered problem detection and error correction loops in the process. AP personnel spent most of their time in reconciliation of information in the forms. Previously, an automation project did result in some improvement, but soon after, the company discovered that one of its competitors was handling this function with just five people compared to its staff of 400.

Ford undertook an ambitious process redesign. Upon detailed analysis, the project team realized that delay and errors were due mainly to redundant information and excessive shuffling of paperwork among the staff. The reengineered processed is illustrated in Fig. 3. Note that the subprocesses inside the dotted box are now computerized.

While we did not have access to more detailed data in the case, we "simulated" subjective judgment by the process owners with reasonable and fuzzy estimates. In other words, we played the role of managers of the process to the best of our knowledge and ability. As with any subjective evaluation, it is important to calibrate so-called expert opinions in practice with proper procedures of learning and training. For example, reasonable consensus must be reached if

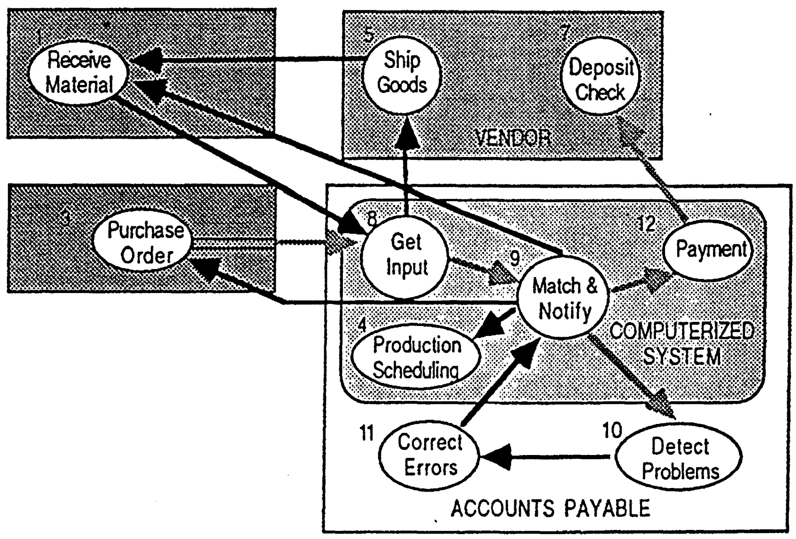

Fig. 3. FORD process: after reengineering.

group decisions are involved. Fig. 4 shows the fuzzy sets used in our analysis.

The following is a sample of fuzzy decision rules for this case:

R1: IF OpDep is a little AND TimeLag is good,
THEN Syn is very large.

R2: IF OpDep is a little AND TimeLag is acceptable,
THEN Syn is large.

R3: IF OpDep is a little AND TimeLag is undesirable,
THEN Syn is medium.

R10: IF OpDep is medium AND TimeLag is acceptable,
THEN Syn is small.

R17: IF OpDep is very large AND TimeLag is good,
THEN Syn is small.

The results of our analysis (using only direct linkages) provide the following structural measures of the Ford Motor Company process before and after reengineering.

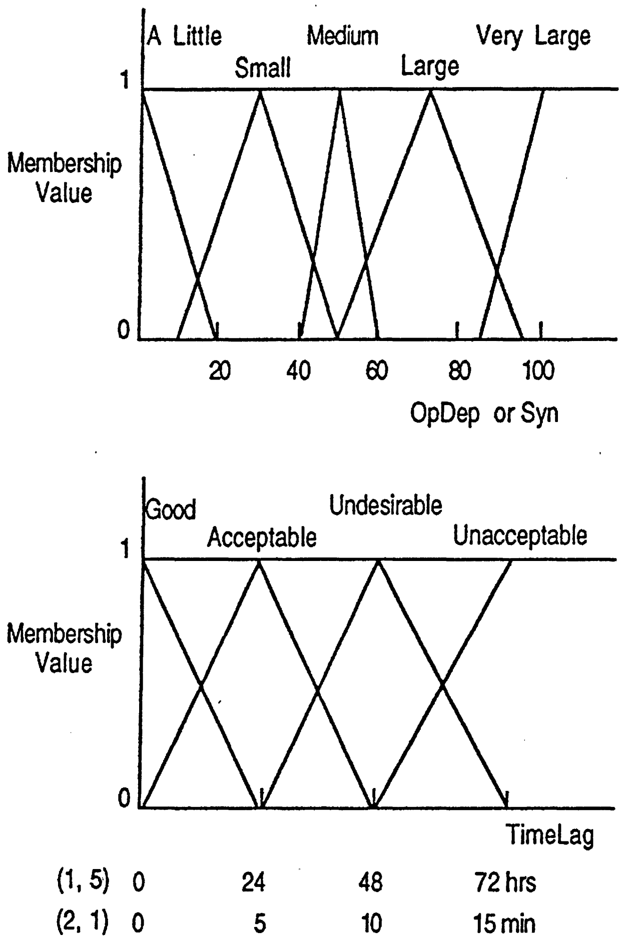

Fig. 4. Fuzzy sets for OpDep, TimeLag, and Syn.

	BEFORE	AFTER
Number of links	15	13
Synchronization index	124.9	188.4
Normalized SynInd	8.32	14.5
Max Norm SynInd	25.82	27.73
Internal Syn Ratio	0.32	0.52

As explained above, the synchronization index is the Euclidian norm of the matrix of defuzzified measures of pairwise synchronization among the subprocesses. As expected, it is higher (188.4 vs 124.9) for the process after reengineering, providing a quantification of the improvement. However, it is possible for this absolute measure to be influenced by arbitrary manipulation of the dimensions of the process. To normalize, we divide with the number of links to obtain an index of 8.32 for before, and 14.5 for after, respectively.

With a given number of links in a process configuration, one can compute the maximum achievable value for SynInd. This provides another useful measure, namely the ratio of the normalized synchronization index to its upper bound. We call this the internal synchronization ratio. In this case, it is 0.32 for before, and 0.52 for after.

6. Conclusion. We have demonstrated an approach to a structural analysis of business processes. Using a procedure that accommodates imprecise attributes of the underlying activities and their interdependence, we derived a quantifiable measure of the efficacy of the process. This is in the form of a synchronization index, and various normalized and relative indices. Given that the ultimate success in financial and accounting terms may depend on many more nonstructural factors external to the inherent characteristics of the work process, such new measures can be of significant use, especially in the context of reengineering. Just as it should be feasible to evaluate alternative engine designs based on their efficiency in converting the heat content in fuel to power, regardless of the economic realities regarding the fuels, our method can lead to meaningful comparisons of alternative designs of business processes.

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BIZNIO PROCESŲ STRUKTŪRINĖ ANALIZĖ REINŽINERIJOS ĮTAKAI MATUOTI

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Straipsnyje yra pateikta biznio procesų struktūrinės analizės metodika. Tikslas yra parinkti tinkamą įvairių tarpusavyje priklausomų veiksmų sinchronizacijos laipsnį. Šiuo būdu alternatyvūs planai gali būti palyginti be kaprizingų masteliavimo efektų, kylančių dėl nestruktūrinių kintamųjų. Sukurta modeliavimo ir analizės metodologija remiasi rezultatais iš fuzzy logikos ir sistemų. Jos taikymas straipsnyje iliustruotas vieno gerai žinomo pavyzdžio pagrindu.