A Planning Framework for Information Integrity for Complex Business Environment characterized by Uncertainty

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Abstract:

This paper investigates the research issue of Information Integrity for complex business environment characterized by uncertainty. Specifically, the paper begins by studying the nature of business environment and its Information Integrity implications. This is followed by discussion on planning framework for homogeneous business environment with 'no surprises,' which the paper identifies as 'closed' system. This leads to the study of informational view of the complex business environment for its Information Integrity implications. The paper argues that complex systems are essentially 'open' systems which with time undertake shifts in IS goal, direction and targets (standards – for plans and programs). These shifts and the uncertainty due to system complexity and other system

environmental factors discussed, go to infest the IS with hitherto unknown errors resulting in loss of integrity. This calls for "adaptive learning" as an requirement for the planning framework. Accordingly then the paper goes on to construct the components of the Information Integrity planning framework for a complex business environment. Specifically, in addition to adaptive learning capability, the Information Integrity planning framework, among other systems, comprises the servo control systems built around the meaningful use of above mentioned pre-estimated targets (standards), so as to bring about improvements in processes, operations, and inputs by controlling them so as to achieve desired outputs and meeting business system objectives in accordance with the pre-determined standards (targets). Finally, the paper presents a conceptual view of the systems representation of the planning framework.

1. INTRODUCTION

The research investigations presented at IFIP TC 11 WG 11.5 Second Working Conference [Mandke and Nayar, 1998] suggested a conceptual information system (IS) model for a business process and argued that whether, in addition to application controls, hardware and software vendors further incorporate error-checking filters into their products, networked computerized information systems contain errors that are made but not corrected. These errors are due to factors of Complexity, Change, Communication, Conversion and Corruption (5 Cs) drawn from system environment, external to application system and overlapping the user environment; resulting in loss of integrity in IS. Research investigations identified these intrinsic integrity attributes as accuracy, consistency, and reliability which, irrespective of nature of use, any IS and information therefrom must satisfy and proposed a need to incorporate on-line learning and error correcting mechanisms in the IS models.

Specifically, to account for errors in IS that are made but not corrected, the research findings proposed a design basis for achieving Information Integrity by incorporation of automatic feedback control systems with error detection and correcting technologies for improved information accuracy, consistency and reliability; technologies that maximize integrity of information systems – Information Integrity Technologies (I*IT). When incorporated, it is such Information Integrity Technology that would also facilitate demonstrating improved integrity of information obtained, rather than merely trusting the computerized information systems.

This brings in the question of implementing Information Integrity Technology which has been considered in the research investigations presented at IFIP TC 11 WG 11.5 Third Working Conference [Mandke and Nayar, 1999-A]. Specifically, given that a triple < entity, attribute, value> as developed by the database research community represents data/information model and given a simplistic situation wherein value part of data/information is expressed in numerical, the investigations presented approaches for quantifying accuracy, consistency, and reliability of the data item of value and, thereby, to build a Cumulative Information Integrity Index (CIII) providing a measurable basis for demonstrating integrity level in the IS. This was followed by presentation of Information Integrity Technology implementation steps.

It is within above framework of design basis and implementational methodology for Information Integrity that this paper discusses the problem of planning framework for Information Integrity for a business environment characterized by uncertainty.

2. BUSINESS ENVIRONMENT NATURE AND ITS IMPLICATIONS FOR INFORMATION INTEGRITY

Traditionally, business enterprises have adopted ‘top-down’ strategies characterized by ‘working according to plan’, emphasizing ‘standardization’ and ‘keeping things on track’, so as to ensure there are ‘no surprises’. Understandably, enterprises sought to produce only ‘standard’ product in high volumes and successfully used control systems tuned to *fixed* 'data/information decisions' to ensure business objectives of operational optimization and cost efficiency, thereby giving the business strategic advantage. The enterprise did have computerized information systems (IS) but they were developed in isolation with emphasis on non-integration, and there was no effort to optimize data or information for improved decision making. The requirement of the business enterprise, therefore, was in terms of automation of functions of 'hard’ components, i.e., of 'mechanical' or 'physical' work wherein physical variables or rather material was transformed or processed or converted so as to add value to the product produced. As a result, the requirements of accuracy, consistency and reliability of information processed through the enterprise were basically seen from the point of view of dependability or trustworthiness of the *fixed* information decisions to which the controls were tuned to optimize the performance of the physical work system.

However, today businesses have become complex: firms combine multiple business units under the same corporate umbrella; global competition results in new strategic alliances; and rapidly changing information and production technologies allow cross pollination of competitive processes, services, and products. In many companies and industries, this increasing complexity is making it difficult for individuals to comprehend organizational purpose and direction. Reduced overheads and transformation have come to stay as the new realities. Furthermore, the reality of data-driven technologies keyed to the flow of digital data throughout an enterprise and the Net, now bombards managers with loads of information that force constant reassessment of their competitive positions. Managers must use this information to ensure that internal operations are efficient and effective [Simons, 1995].

This environment of constant challenge and change brings in perpetual uncertainty in business environment which is only further accentuated with pressures of achieving business objectives of effectiveness and efficiency through requirements of mass-customization, agility – focused on customer responsiveness, IT driven market differentiation, supply chain synchronization by integration maximization and financial optimization for strategic advantage. It is to meet with this challenge that business enterprises of today have a requirement to adapt 'customer/market-driven' strategy characterized by 'continuous innovation', emphasizing 'meeting of customer needs' and 'customization', so as to make the business a 'learning' entity ('empower' the business) to meet the challenge of continuous change and uncertainty. And it is to meet this challenge that the business enterprise has a further requirement for utilizing data/information decisions 'smarter.'

This calls for automation of 'informational work' carried out by the soft components of the enterprise wherein 'data' is seen as raw material, 'data processing or transformation or conversion' as the system function and 'data product' or 'information' as processed data used to trigger information use (decision making stage included) so as to deliver to the controller of the physical work system the information in the form of *flexible* information decision, i.e.

'optimum' and hence 'improved' information decision so as to add value to the product. As can be seen, this is a networked, computerized information system and is characterized by (a) computing processes under system function that include microcomputer and telecommunication and (b) pre- and post-processing stage communication channels at various data/information processing nodes, that are people based and include data communication and transaction processing networks with world-wide reach [Mandke and Nayar, 1998].

For achieving strategic advantage, what a business enterprise functioning in an environment of uncertainty is thus faced with is the task of adding value to the information processed by the business process IS view in the form of *flexible* information decision. And this in turn then calls for the requirement of accuracy, consistency and reliability of information processed through the enterprise to be seen from the point of view of dependability or trustworthiness of the *flexible* information decisions to which the controls are to tune so as to optimize the performance of the business enterprise in the presence of uncertainty in the business environment.

3. PLANNING INFORMATION INTEGRITY FOR HOMOGENEOUS BUSINESS ENVIRONMENT WITH 'NO SURPRISES'

As explained in Section (2), business enterprises seeking to produce only 'standard' product in high volumes with emphasis on operational and cost efficiency for strategic advantage work with *fixed* design information decisions. In other words, their business processes are characterized by processing of 'structured' and 'periodic' information (for example, engineering design information as in case of electrical or mechanical systems whose physical structures are so very well understood). Figure (1) gives a systems representation of an automated engineering system producing 'standard' product in high volumes.

First real applications of computerized information systems were for such businesses and understandably they were generally justified purely on the cost reduction aspects of processing structured and periodic information, the work clerical in nature being the obvious choice. The information 'content', or the degree of strategic uncertainty, in the information processed by these applications was minimal.

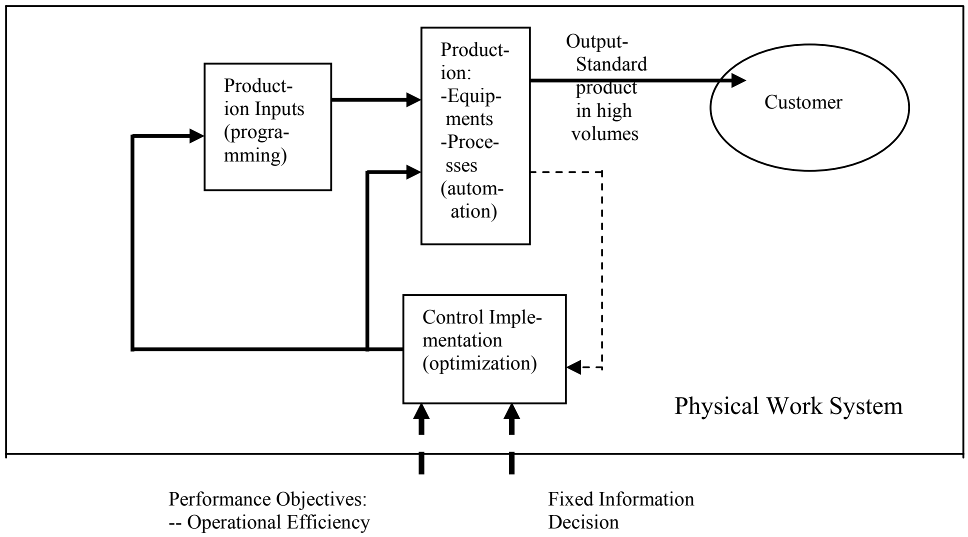

Figure 1. Systems representation of an automated production system producing "standard" product in high volumes

As most business information processing installations became application-oriented as above, there came into existence an application for payroll, a different application for inventory status, another for accounting, cost distribution, sales analysis, and so forth, with emphasis on how to utilize the computer efficiently. With time, however, businesses became aware of the computer's potential for solving management problems involving requirements of planning, direction and control. Here again, as problems were identified and new techniques developed, each became a new application: production control, inventory control, sales forecasting, project management, maintenance scheduling, quality control. Each is a new computerized information system, and has its own sources of information, terminology, and classification methods [Mathew, 1971].

Emphasis thus was on non-integration and physical systems were still kept simple. However, there were sources of errors such as hardware errors, data entry errors, accidental or intentional failures (including human failure), etc. Thus there was the problem of accuracy, consistency, and reliability of information processed even in these otherwise highly non-integrated information systems for businesses seeking to produce ‘standard’ product and normally dealing with structured and periodic or repetitive information.

The reason why one has chosen to elaborate on above business IS development process is that it is the ‘standardized’ nature of the business and the ‘structured’ and ‘periodic’ or ‘repetitive’ nature of its information processing requirements, that then have contributed to the design of controls for ensuring integrity (accuracy, consistency, and reliability) of information processed by the business IS for ‘standard’ product, high volume, low cost models of business enterprises analyzed above.

Specifically, in these businesses as no variation in the information and material transformation processes is desired, view is taken that standard operating procedures can specify how every transformation/process/action should be performed. Control is then achieved by monitoring that, process/action (machine and human) is performed as specified. Efficiency studies, internal control standards, and desired safety levels are then used to develop detailed operating procedures. This is the ‘process’ control approach to ensuring integrity. And another approach is to control output - information in case of business IS - by carefully selecting input, that is by controlling data collection process. This is the ‘input’ control approach to ensuring integrity.

Within above framework, for the business IS under consideration, external controls, administrative controls, IS operational controls (comprising input controls, processing controls, and output controls), documentation controls, and security controls are traditionally proposed to be implemented right at the systems analysis stage, so as to ensure the integrity, i.e., accuracy, consistency, and reliability of information processed by the business IS [Burch, Jr. and Sardinas, Jr., 1978]. Figure (2) gives a systems representation of these internal controls in an information system for a homogeneous business environment characterized by ‘no surprises’ considered here.

And as mentioned in Section (1) and as indicated through Figure (2), in spite of controls implemented right at design stage, these computerized information systems contain errors that are made but not corrected [Mathew, 1971; Mandke and Nayar, 1999-B]. There are several reasons as to why as businesses developed

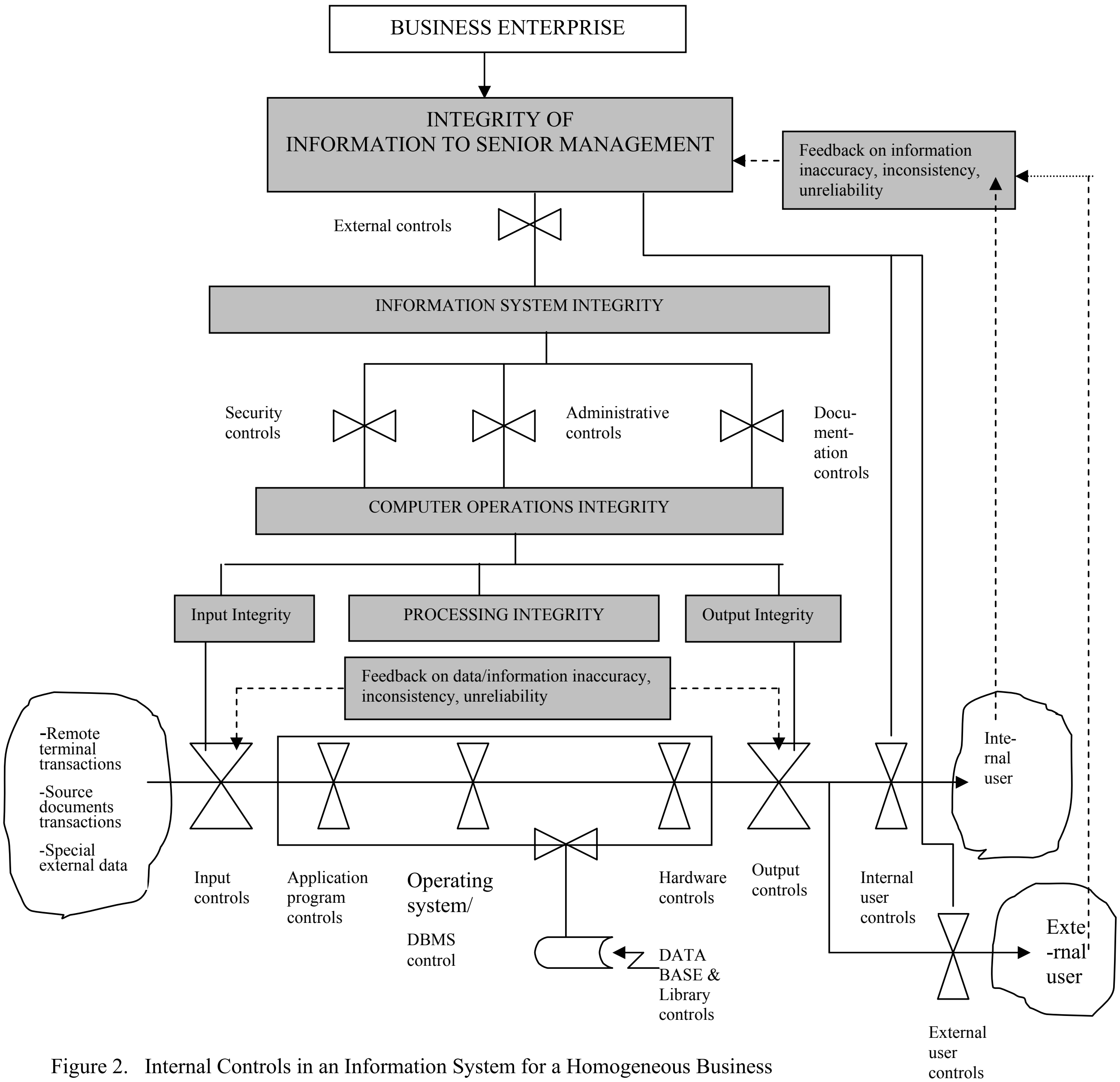

Figure 2. Internal Controls in an Information System for a Homogeneous Business Environment characterized by 'no surprises'.

more and more “applications,” they found that while solving some problems, they had created several new ones; the key reasons being:

(i) There is more information available than anyone can digest or evaluate (the problem of information overload).

(i) There are frequently conflicts between the results from two applications; for example, a report on employee absenteeism from the payroll application does not tally with the absenteeism rate derived from the personnel application (absence of standardization).

(ii) When the organization attempts to solve problems involving several departments, there is no relationship between the data in the several applications - the decisions in the product mix will certainly affect inventory investment, but unfortunately the production control application and the inventory control application do not communicate with each other (problems due to emphasis on integration minimization).

(iii) With increased “applications”, the business IS has now acquired a complex structure and as a result it has started encountering types of information failures not encountered earlier (for example, failures that come with delayed time and with complex fault mechanisms like those due to the latent errors made during IS development life cycle phases, etc.).

Thus, while on the one hand the computerized information system increased the efficiency of the business processes and made information systems integral to both operational and managerial functions, on the other hand, ironically, it introduced uncertainty in otherwise seemingly homogeneous information environment of the business process, in turn requiring further assurance on integrity of information for improved business performance and strategic advantage.

4. INFORMATIONAL VIEW OF COMPLEX BUSINESS ENVIRONMENT CHARACTERIZED BY UNCERTAINTY

Many businesses recognized this problem and proposed integrated information systems serving several departments and functions within an enterprise. This led to realization of value of information as a basic resource of the enterprise and resulted in abandoning the application-by-application approach. In the beginning what accelerated this process was the invention of microprocessors which led to a dramatic increase in the use of computers in business and in daily human life, to a point where today, by one estimate, these 'data embedded' systems outnumber humans on our planet [Storey, 1996]. Subsequent push in this direction came as real-time computer systems became as common as batch systems; and the Net became the reality.

These developments led to yet another technology in the form of data driven technology. Specifically, in the manufacturing sector, in the form of data driven automation, it demonstrated the benefits to be reaped from manufacturing 'smarter'. Further, combining the power of desktop information processing and high speed telecommunications, it began facilitating on-line transacting which in due course became the best known public face of electronic commerce activities such as internet book-buying and on-line stock-trading. And in the industry's supply chain (linking manufacturers, assemblers, distributors, marketers and customers), it presented supply chain planning (SCP) solutions offering opportunities for inventory reduction and shortening supply chain by saving on time [Mandke and Nayar, 2000]. All these are the examples of using information 'smarter.'

4.1. Centrality of Informational Work System in Complex Business Enterprise characterized by Uncertainty

Unlike the businesses wherein only 'hard components,' i.e., only the 'physical work' (in the form of material transformation) is considered for automation with no effort to optimize data or information for improved decision making, now, what have thus emerged are the business processes that have *further* requirement for utilizing data/information 'smarter.' This calls for automation of 'informational work' carried out by the soft (design (innovation) and planning & decision (programming)) components of the enterprise wherein every possible business 'data' (internal as also external) is seen as raw material, 'data processing or transformation or conversion' as the system function and 'data product' or 'information' as processed data to trigger information use (decision making included), so as to deliver 'information decision' (to the control stage of the physical work system) in the form of information to add value to the product.

Using data/information 'smarter' is an application of *flexible* automation accounting for product innovation, customer needs (product requirements), and for constraints of costs and capabilities – a structural variant from 'inflexible' automation of traditional businesses [Spectrum series, 1987; Mandke and Nayar, 2000]. Specifically, the *flexible* automation is becoming possible due to (a) availability of on-line computers, (b) computers providing capability for moment by moment optimization of processes and decision making, and (c) availability of system integration capability so as to yield a computer integrated system for attaining business objectives (see Fig. (3)).

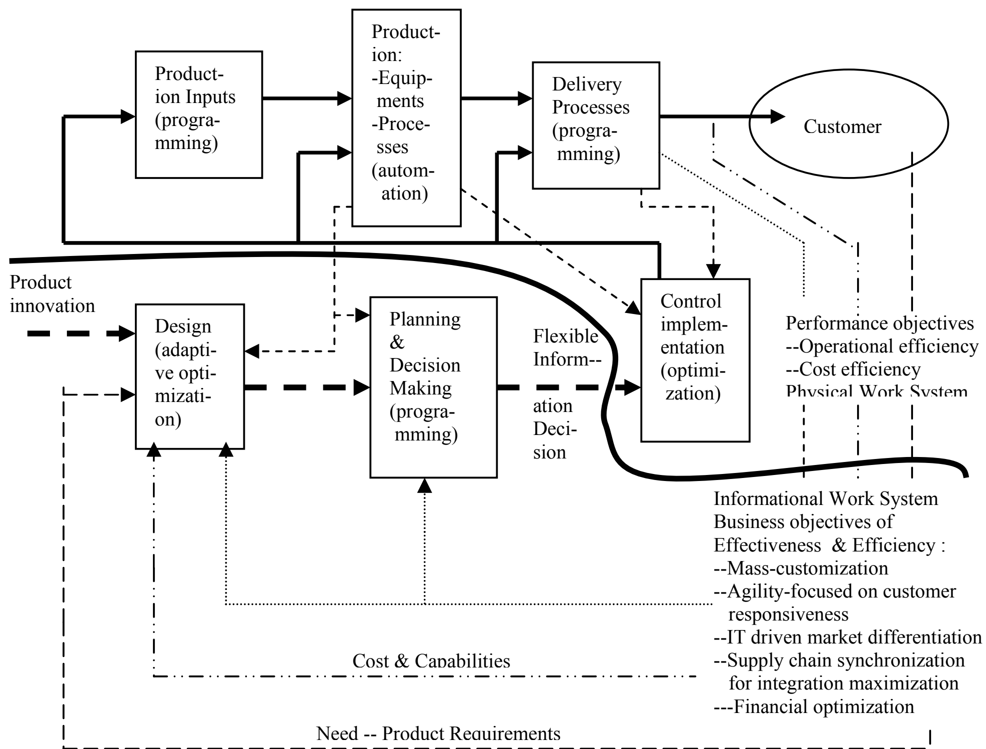

Figure 3. Systems representation of computer-integrated complex business enterprise activities showing interrelationship between informational and physical work systems

What makes it possible now to 'put it all together' in a total design, manufacturing and delivery system is the technological reality of digital data as medium of information across the enterprise [Spectrum series, 1987]. Further, most importantly, such systems can be applied to both hard components of manufacturing like processes, machinery and equipment, and soft components like information flows and data bases—the informational work systems**.**

4.2. Core Business Process IS View

It is within the framework of this centrality of the "informational work" in achieving agility and adaptivity in the enterprise's functioning and handling large and constantly changing variety of produced items, that a conceptualization emerges to model all business procedures as data processing procedures, i.e., they all process data in some manner to deliver information for use in decision - making. Taking the triple $< e, a, v >$ to represent a data/information model, Mandke and Nayar while studying information flow model for integrity analysis identify 10 data processing activities corresponding to the Data Origin Stage, Conversion Stage and Information Representation & Use Stage of the informational work system [Mandke and Nayar, 1999-B]. Taking this delineation of data processing activities and putting them together with the requirements of information flow modeling for the Decision - Making Stage , then gives an IS View of the Business Process as given in Figure (4) (see correspondingly designated black box).

4.3. Errors in Business Process IS View and their Information Integrity Implications

Finally, while on the one hand incorporation of data driven technologies offering business process IS view opens for business processes benefits of customer responsiveness, larger markets, and low information costs leading to opportunities for financial optimization for strategic advantage, on the other hand, due to factors of 5 Cs (see Section (1)), this business IS view is also subjected to errors in data and information processed by it. Specifically, research investigations presented [Mandke and Nayar, 1999-B, 2000] argue that errors in IS view can be modeled to include:

(i) errors with deterministic descriptions caused due to events singular in nature like software failure, denoted by $\eta_{sing,}$, and

(ii) errors with stochastic descriptions caused due to:

a) general causes like mechanistic failure, service disruptions, etc., denoted by η_g,

b) human judgmental factors operating at human-IS interface, denoted by $\eta_{j,}$ and

c) systems factors (external and internal to IS) like a merger, regulatory activity, legislative action, activity of a competitor, acquisition of a new software or hardware, etc., denoted by η_s.

The applicable combinations of error types occur at various data processing activities under IS stages. For the purpose of the research investigation at hand, what is important is to recognize that these errors in IS view of the business process result in loss of integrity at the data origin, conversion and output stages and at pre - and post - conversion stage communication channels of the business process IS view model, thereby rendering data and information processed inaccurate, incomplete, not up to date and unreliable[Mandke and Nayar, 1998, 1999-B].

Figure (4) gives a systems view of complex business process IS view characterized by uncertainty incorporating error components and presenting emergent Information Integrity implications.

5. ADAPTIVE LEARNING – ON THE NATURE OF INFORMATION INTEGRITY PLANNING REQUIREMENT

As argued in Section (3), the computerized information system first found its way into business systems basically on the cost reduction aspects of processing structured and periodic information in high volumes. That is to say, the reality models of businesses were seen more as ‘closed’ systems and, therefore, information ‘content’ in the business information models was neither considered to impact the system environment nor the system environment was considered to have impact on them. In fact, the proposition was that the assembly line business processes that facilitated delivering ‘standard’ product in high volumes were governed by deductive models and were basically concerned with input, process and output information items that were structured, periodic and, hence, accurately predictable (minimum information content). Of course, there were stochastic errors due to mechanistic failure or service disruptions in respect of physical (hardware) components or due to behavioral failures (unpredictability) of human components, and to account for them the internal controls were brought into the picture as explained in Figure (2).

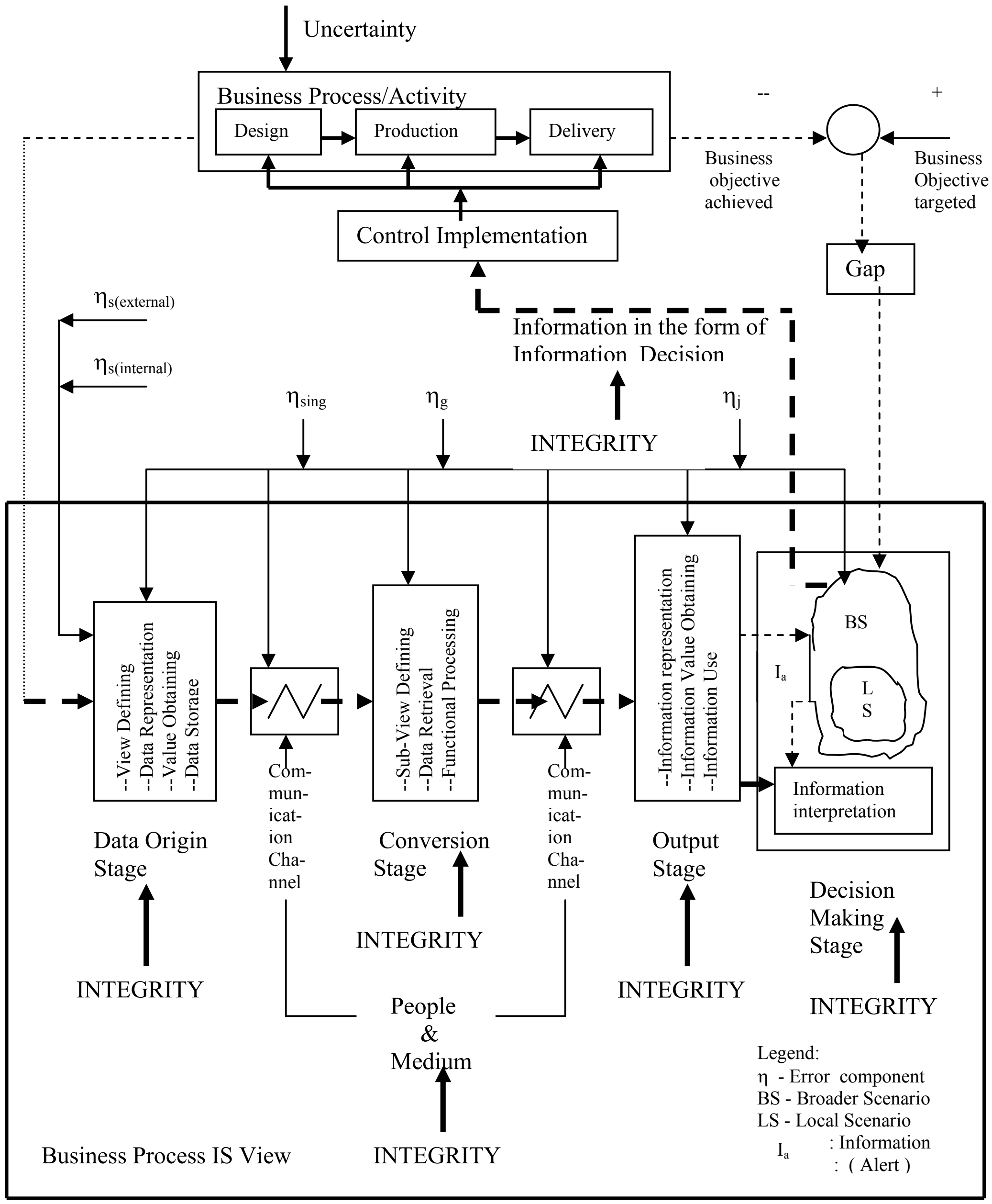

Figure 4. Systems View of Complex Business Process IS View characterized by Uncertainty incorporating Error components and presenting emergent Information Integrity implications

However, this did not prove adequate. Because, as explained in Section (3), while on the one hand the very business benefits accruing from 'applications' and the very fear of failure, in case of not taking the beaten path, paved a way for increased but *ad-hoc* (repair and service mentality) use of computerized information systems giving *for the time being* improved cost-efficiency and productivity and hence profits, on the other hand, *with time*, came:

(a) change of objective and of direction presenting an opportunity (realization that the computerized information systems are also useful to solve management problems involving requirements of planning, direction, and control);
(b) in the wake of technological developments, dramatic acceleration in system integration for further business benefits (environmental impact);
(c) new risks bringing in hitherto unknown information failures (for example, increased integration exposed even inner IS modules to environmental impacts. To elaborate, sometimes this interaction with external systems may be relatively simple. For example, a module might turn *ON* or *OFF* an external actuator, or sense an external switch. In other cases the interaction may be more complex, either because of the nature of the information being passed, or because of the inherent complexity in the external system. And here it may be pointed out that often the most complex interfaces involve human users (internal as also external to the IS). As a result such human-IS interfaces are often required to pass a great deal of information to human users, and it so happens that human users are complex and unpredictable which in turn adds to the complexity and uncertainty in the IS external environment [Storey, 1996]).
(d) change of objective and of direction impacting the environment (for example, opting for business objectives of customization and IT-driven differentiation changed the way people look at business); etc.

And, as argued in Sections (1) and (4), all this understandably only introduced errors in the IS that are made but not corrected in spite of controls.

Certainly the research investigation at hand does not intend to exhaust all sources of IS errors in computerized information systems. But based on the analysis here it is pointed out that it is inadequate to have the reality model of IS as a 'closed' system. In fact, as shown above, even the IS for the 'standard' product, high volume business model, was not a closed system. In the thick of integration minimization approach, 'motivation' of increased profits led to incorporation of ‘applications.’ While planning, even when recourse was taken to ‘methodism’ by holding on to established patterns of action by ad-hocism in the form of application-by application approach [Dorner, 1996], eventually a new ‘direction’ emerged by in the form of relevance of computerized information systems to management requirements of planning and control; leading to shift in IS goal from that of operational efficiency to that of planning and monitoring effectiveness and operational efficiency. Similarly, over time technological developments also brought about shift in business goals; moving the goal from cost efficiency to that of financial optimization (environmental influence), and that in turn led to emergence of business model with emphasis on ‘continuous innovation’ and ‘mass-customization’ for increased market share – a structural variant of the ‘standard’ product, high volume business model.

Changing time sequence (dynamics), shift in goal, identification of new direction, impacting or being impacted by the environment – all these are open system characteristics and indicators of ‘adaptive learning’ capability that the business IS has thus been demonstrating.

And even as, accordingly, the IS was being impacted and also impacting its environment as above, because of the closed system view of the business reality model, the IS was being infested with increased information errors (accruing from Design, Development, Deployment (testing), Data and Detection (auditing) errors (5 Ds)), resulting in loss of integrity which actually is detrimental to the very business objectives. While on the one hand this unequivocally establishes the Information Integrity Imperative, i.e., the trustworthiness or dependability of Information Integrity as the competitive advantage for a business environment characterized by uncertainty (how does one further integrate for increased effectiveness and efficiency while ensuring minimum, if not nil, IS errors? By incorporating measures for improved Information Integrity), on the other hand, it suggests a need to manage ‘conflicting real goals’ if one is to meet objectives of maximization of system integration for increased markets and financial optimization and that of requirements of Information Integrity for the same.

As business IS exists in the real world, in concrete terms, managing these ‘conflicting real goals’ calls for *maximizing* information about objects (some concrete, such as machines, stocks and buildings, accounts and sales forecasts), environment (physical, organizational, personal), people, rules, norms (often deeply engrained ways of doing things and modes of thinking and practice), and commands (such as computer programs); so as to continuously learn about shift in IS goal, emerging new directions, strategic uncertainties presenting new opportunities and risks, design innovations, setting new improved targets (standards), improvements in processes and procedures, improved inputs and outputs, etc.

In the vocabulary of systems engineering, in the form of business IS, what one has thus at hand is an *adaptive learning* system which is customer responsive in the same way as a living organism is environment responsive. And as the Information Integrity design has the requirement to detect (learn) and correct (control) the IS errors in such an adaptive learning IS, it is expected that it (I*I design) will also demonstrate such adaptive learning capability so as to detect IS errors and correct them for the complex business process IS View of Figure (4).

6. A PLANNING FRAMEWORK

As explicitly argued in Section (5), the crux of adaptive learning is in managing *maximal* information in a dynamic open system environment of complex business IS in the presence of uncertainty. Research investigations suggest I*I design basis by incorporation of automatic feedback control systems [Section (1); Mandke and Nayar, 1998]. As the concept of 'feedback' is implicit in 'learning' mechanism design, it is proposed that the "automatic feedback control system" conceptualization of Information Integrity Technology may be further extended to develop an Information Integrity planning framework for complex IS environment characterized by uncertainty.

Specifically, it is suggested that, in an open environment, system capability of adaptivity is characterized by learning about any changes, more appropriately 'shifts,' that could be warranted from time to time in the system goal, direction and targets (standards which understandably cover plans and programs). For an complex information system user (internal as also external) each of these three (i.e. goal, direction, and targets) are nothing but 'information items.' That is to say, as mentioned in Section (5), in the task at hand of managing the conflicting real goals of requirements of business objectives and that of Information Integrity so critical in achieving them (business goals), the IS user must appropriately maximize these information for each of these information items and then, in the fold of the user's learning act, which in fact is an IS in its own right with stages of detection/estimation/prediction (forecasting), alternatives (opportunities and risks), and selection or decision (evaluation and judgement), process the maximized information for each of the information items so as to learn or to select or to decide on the newly emerging goal or direction or target (standard) as the case may be. Toward the design of the planning framework, this is the first instance of the extension of ‘feedback’ concept for improved estimates of the information items of goal, direction and targets (standards); thereby reducing the IS errors in the context and improving the Information Integrity .

This brings one to the issue of requirement of continuous innovation for business objectives such as that of mass-customization for increased market share giving competitive advantage. These are the product or service design innovations and they should be so implemented that, while on the one hand they (innovations) facilitate the business exploiting the opportunity space for meeting the business objectives, on the other hand, they (innovations) should necessarily keep the business clear of risks. Towards this the planning framework may then develop constraints within which then any design innovation will have to be worked out for implementation. Needless to say, processes determining the design innovation (see Figure (4)), the correct opportunities and correct risks, and the goal and direction are also information processes, and to ensure the Information Integrity of the business IS it is important that integrity of these information processes is also assured.

Having thus provided for the innovational design strategy as above and that, too, within the framework of sensed (determined) perceptions of the adaptive changes in the IS, the second instance of extension of the ‘feedback’ concept could be brought in to the picture. Specifically, it may be built around the meaningful use of above mentioned pre-estimated targets (standards), so as to bring about improvements in processes, operations, and inputs by controlling them so as to achieve desired outputs and meeting business system objectives in accordance with the pre-determined standards (targets).

Incidentally, use of targets (standards) to build systems for controlling processes and inputs, so as to obtain desired outputs and system performance as per pre-determined standards, is an established engineering approach. Specifically, this is a class of control systems of great practical significance – the so-called *servo-mechanisms*, or *sevos*, for the short. In its classical definition, a control system is referred to as a servo (system) if the output is designed to follow as closely as possible a given reference signal [Elgerd, 1967]. Specifically, what it does is to measure the system output, then obtain the error in the form of deviation of the output from the reference signal, and then use that error signal so as to control the system performance in such a manner as to minimize, in some sense, the error signal; that is to make the output as close to the reference signal as possible. As can be seen servo systems are essentially feedback systems and further they can be applied to both linear and non-linear systems which is what incidentally our business process information systems are.

For the investigation at hand, the system output can be what the management literature terms as "key success factors" or "critical success factors" or "critical performance variables" (financial measures, internal business measures, for example [Melville and Hafen, 1999]) that go to define the business process performance. The reference signal for each key success factor is the respective target, i.e., the pre-determined standard so developed as to ensure meeting the business objectives. The servo system implemented based on the meaningful use of pre-determined standards would then continuously measure the business performance output, obtain its deviation (error) from the pre-determined standard desired or expected, and then, based on the extent of error or deviation, control (improve or innovate or adjust locally at the field level) the process, procedure, operation or input, as the need may be, so as to make the system output as close to the pre-determined standard (in some sense zero error or deviation). Thus as can be seen, unlike in the case of traditional business models where controls are pursued through requirements of static, pre-determined standardization of processes and inputs, here controls utilized see that outputs, i.e. business performance outcomes, meet pre-determined standards (targets) which, through the first instance of feedback application, keeping in mind the open system character of business IS, are also tuned to the process of adaptation for future advantage.

It goes without saying that the servo systems implemented as above are also IS, and hence are liable to contain errors that are made but not corrected; in turn requiring measures for ensuring their integrity so as to ensure Information Integrity of the total business IS system.

There is one more important aspect. In order to ensure Information Integrity of the complex business IS in the presence of uncertainty, what have emerged here are the information processes for the following: (a) for improved dynamic estimates of goal, direction and targets (standards – for plans and programs) – feedback systems for adaptive learning; (b) for correct estimates of opportunities and risks in the light of strategic uncertainties, (c) for continuous design innovations for business objectives, (d) for improving processes, operations, procedures so as to meet servo objectives, and (d) for implementing servo control systems for meeting the business objectives. As each of these by themselves are complex systems, as explained in Section (4), they all will have IS errors; thereby requiring that, for the purpose at hand, Information Integrity for each of them be assured. As one is dealing with maximal information at each stage here, one of the important source of errors for each of these information systems is the accuracy, consistency and reliability , i.e., integrity of information each of these processing systems receive. As can be seen this is the problem of internal control for the complex business IS and it goes without saying that, amongst other things, the integrity of the information items received by each processing systems will also have to be assured if, as mentioned above, each of these processing systems and, thereby, the complex business IS under consideration is to have Information Integrity.

This totality then gives the Information Integrity Planning Framework for a complex business environment characterized by uncertainty (see Figure (5) for a conceptual view giving a systems representation of the Planning Framework).

7. CONCLUSION

The task of dealing with a complex business environment characterized by uncertainty is the challenge of working with an open system. Components and sub-systems of an open system are also open systems in their own right and they coordinate and interact amongst themselves by processing information. As a result whatever else a business does, make automobiles, sell real estate, run hotels, or whatever, through its IS view, it processes information. And this IS view contains errors, resulting in loss of integrity; which is detrimental to business objectives. This establishes Information Integrity Imperative whereby the dependability or trustworthiness of information, i.e., Information Integrity emerges as the key factor determining competitive business advantage.

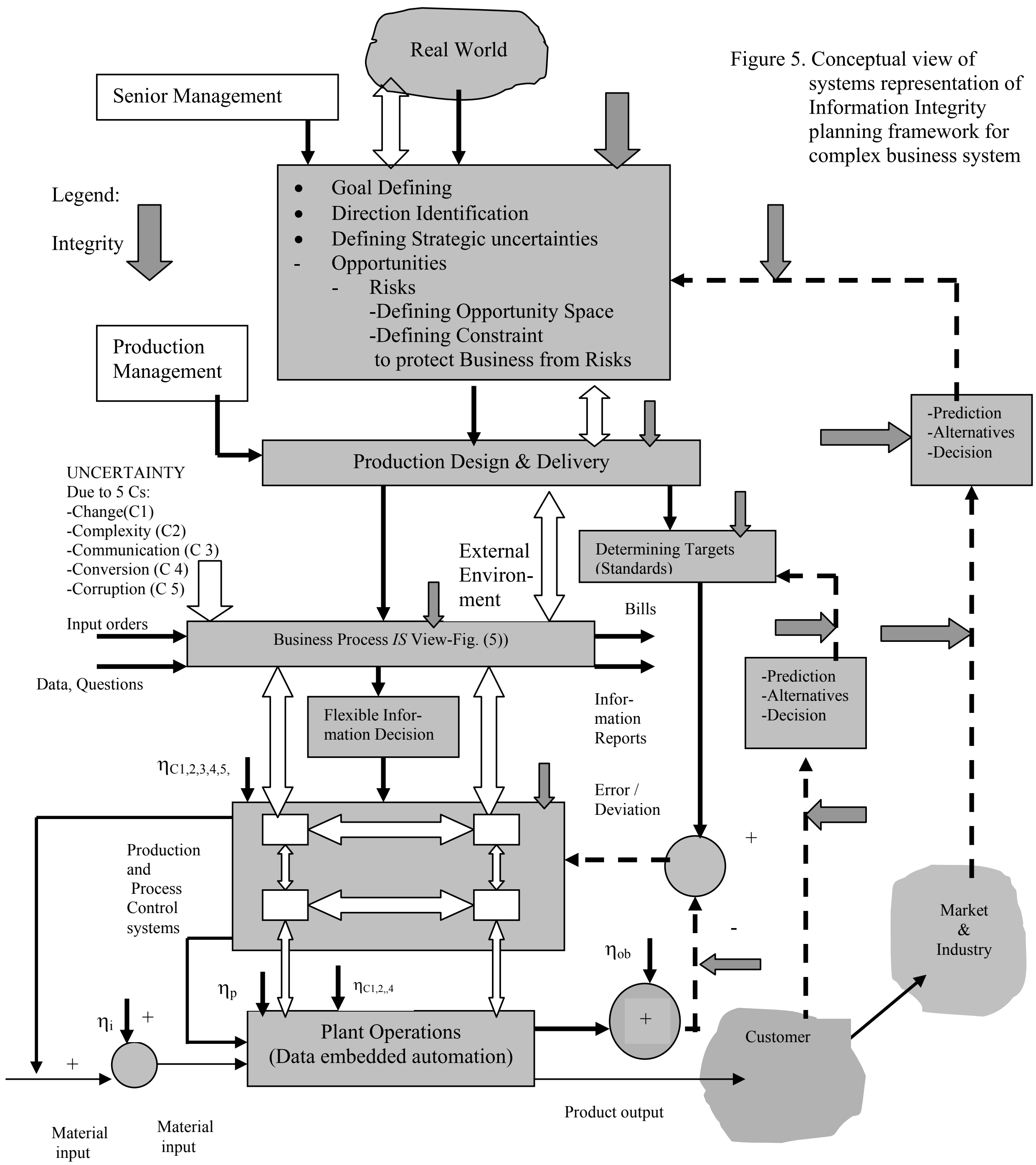

Figure 5. Conceptual view of systems representation of Information Integrity planning framework for complex business system

Traditional Information Integrity implementation approach based on the assumption of the reality model of business system as a closed system is ad-hoc, characterized by "application-by-application" strategy, and, as a result, unable to respond to needs of complex businesses operating in the world of change and uncertainty. This calls for a view of Information Integrity planning framework which empowers Information Integrity design and implementation approaches with an ability to learn about the way business in its form as an open system interacts with its environment and then to accordingly set and achieve the integrity targets so as to be instrumental in business system remaining on the path of growth.

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