Journal of Information Technology Management

ISSN #1042-1319

A Publication of the Association of Management

GOAL-DRIVEN MEASUREMENT FRAMEWORK FOR SOFTWARE INNOVATION PROCESS

SUBHAS C. MISRA
CARLETON UNIVERSITY
scmisra@connect.carleton.ca

VINOD KUMAR
CARLETON UNIVERSITY
vinod_kumar@carleton.ca

UMA KUMAR
CARLETON UNIVERSITY
uma_kumar@carleton.ca

RAJENDRA MISHRA
CARLETON UNIVERSITY
rp_mishra@yahoo.com

ABSTRACT

It is important for modern day software organizations to remain competitive in the market. Being innovative is important for the survival of the organizations. The nature of innovation processes in place in different organizations varies. It is important for organizations to measure and continuously improve the innovation processes. In this paper, we present a goal-driven measurement framework for Software Innovation (SI) processes. We also present a roadmap for the implementation of the framework.

Keywords: Software innovation, process, measurement.

INTRODUCTION

An organization's product often finds itself competing with "hundreds" of other similar products in the market, and software organizations are no exceptions. Staying competitive in the market is a *mantra* of survival of modern day software organizations. The above statement is testified by our observation of the frequent release of newer (enhanced) value-added versions of the same product, or of the release of entirely new suites of products potentially targeted to serve the market needs. Most well-established software organizations have an explicit or implicit process structure in place to innovate their products. Whereas in some organizations the process that leads to the development of innovative products is well-defined, in others there is no clearly established process, and innovation activities are performed in an *ad hoc* manner.

The nature of the innovation processes, and the degrees of their adoption vary between organizations. Irrespective of the process in use in an organization, it is

important to realize the importance of measuring the processes in place so as to enable the improvement of existing processes [Carneiro, 2000]. It is, therefore, important to define metrics that would help in measuring innovation processes. Often the goals of measurement are not distinct enough to conduct the measurement activities in an useful manner. In this paper, we propose a goal-driven measurement framework for innovation processes that tries to link the metrics to be used in the innovation processes with the business goals. The business goals are used to define the process improvement goals and the measurement goals, which are finally used to establish the metrics that can be usable for measuring the innovation processes. The questions serve as tools for the verification of success of an innovation effort.

The goal-driven measurement framework is based on the ideas and experiences reported by Basili [1], Park *et al*.[14], and Rombach [17]. It uses the Goal Question Metric (GQM) approach [2, 19] developed by Victor Basili and his associates at the University of Maryland. GQM has received wide industrial acceptance in the past in different industrial and pilot projects, the results of some of which are documented in [5], [8], [9], [15], [16].

In the following sections we present the framework we propose for use in SI, propose the different metrics that can be used in a typical innovation process measurement program, and then present a road-map one can use to implement our framework.

SOFTWARE INNOVATION

The term "innovation" refers to the act of creating something new, normally something *breakthrough* in nature that did not have significant prior existence in the same form.

In the context of general product development, [7] defined innovation as a new process of production. [18] defined innovation as a process by which an invention is first transformed into a new commercial product, process or service. [20] defined innovation as a high-risk concept that is new to the sponsoring organization.

Kumar *et al*. [10] have described "innovation process" as a system of organized activities that transform a technology from idea to conceptualization. There exist different models of innovation, viz., Stephen Kline's Chain Linked Model, Ralph Gomory's Circle Model, Alic Brascomb's Model, and John Ziman's Neural Net Model, Departmental Stage Model, Activity Stage-Gate Models, Decision Stage Model, and Conversion-Process Model. Without delving further into the discussion of the different process paradigms, we show in the following sections how we can have process maturity models of innovation. For interested readers, a detailed discussion of different models of innovation can be found in any good book on innovation (e.g., [4]). Irrespective of the process model used, most innovation processes typically initiate with the identification of opportunities, and end with final product development and commercialization of the breakthrough product.

Intuitively, most of the above generic innovation process models also apply to software products. Literature on software innovation is scarce. A few pieces of literature that document previous work performed on empirical studies with software innovation are [6], [11], [12], and [13].

FRAMEWORK

To design the intended goal-driven measurement framework for SI, we need to determine the ways in which we can control the innovation processes by setting up quantifiable innovation process goals that need to be achieved, and then determining the measures that need to be collected to achieve the goals. The details of the SI process framework are shown in Figure 1. Broadly speaking, the framework consists of three main levels – a *conceptual level* that defines the goals of innovation, taking into account different considerations such as business intents, and quality requirements; an *operational level* that characterizes the assessment or achievement of goals through the interrogation of specific sets of questions whose answers would lead to the assessment of the goals; and the *quantitative le*vel that defines a set of metrics that can lead to the collection of measurable data that can answer the questions asked in the operational level.

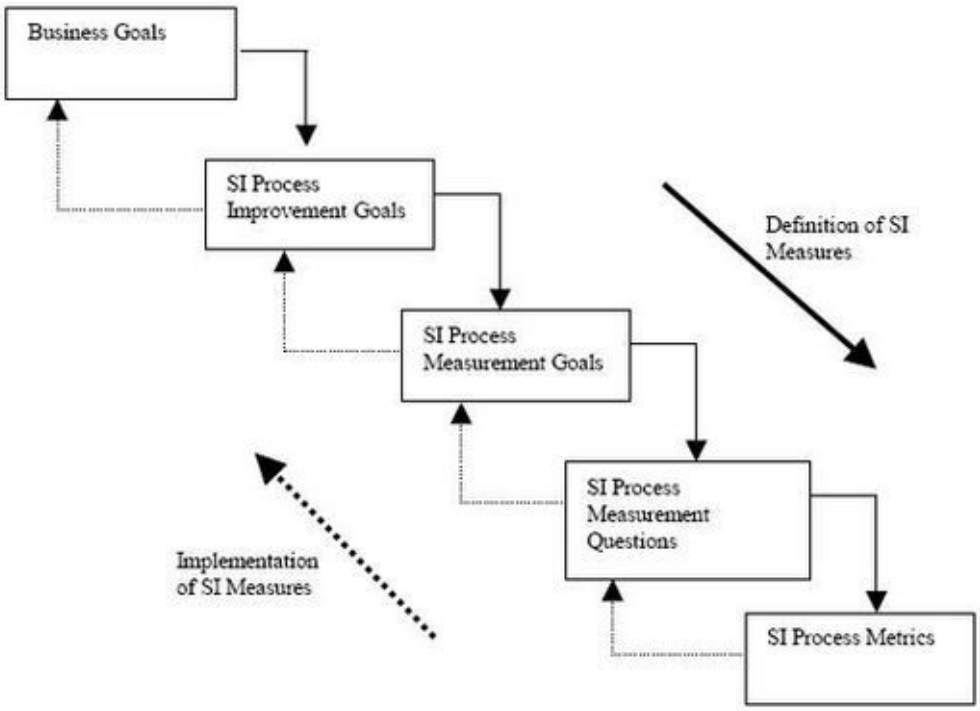

Figure 1: The SI goal-driven measurement framework

In this SI goal-driven measurement framework, the process improvement goals are derived from business goals, which in turn dictate the process measurement goals. The process measurement goals serve to define the process measurement questions, which help to define the process metrics. These process metrics are used to collect SI process data that might help in answering the measurement questions, measurement goals, and process improvement goals.

The goals identified in the above steps are then analyzed further to generate *sub-goals*, which may be considered as manageable goals that "make sense" and are usable in the next step in the process measurement framework. This is shown in Figure 2. As the Figure shows, each higher-level goal in each of the phases is broken down into a lower-level sub-goal.

Business Goals: The foremost activity that needs to be conducted for goal-driven measurement of software innovation is the identification of business goals that guide the innovation activities. The identification of business goals phase might require different iterations of refinement in order for them to be made useful for the next phase involving the identification of process improvement and measurement goals. Of all possible, business goals, mainly those that have a potential effect on the SI process, are of primary interest in this framework.

Process Improvement Goals: The process improvement goals are derived from the business (sub) goals. The process improvement goals are identified keeping in mind the business intents and rationales behind the innovation activities. The goals are obtained after several iterations of refinement to ensure that all aspects of process improvement are captured.

Process Measurement Goals: The process measurement goals are derived from the process improvement (sub-)goals, and the issues and concerns governing the innovation process improvement. These measurement goals will provide the basis for the identification of the measurement questions and the metrics. Therefore it is very important that the measurement goals are clear enough to sufficiently granular levels to be able to formulate the measurement questions. To formulate the measurement goals, one has to first identify the process improvement sub-goals, identify the actions that need to be undertaken to arrive at those goals, analyze the actions corresponding to these goals that would lead to the identification of measurable quantities.

GQM: Once the innovation process measurement goals are identified, the GQM methodology is applied to each of the measurement goals that are identified to derive the metrics that would lead to the quantification of the measurable goals. Therefore, according to the GQM methodology, corresponding to each measurement goal, one or more questions are formulated, whose answers are capable of measuring the goals. For each of these questions, suitable metrics whose values help in answering the questions are designed. The questions that are designed in the GQM methodology should be simple enough so that one can collect data using the metrics identified in the third phase.

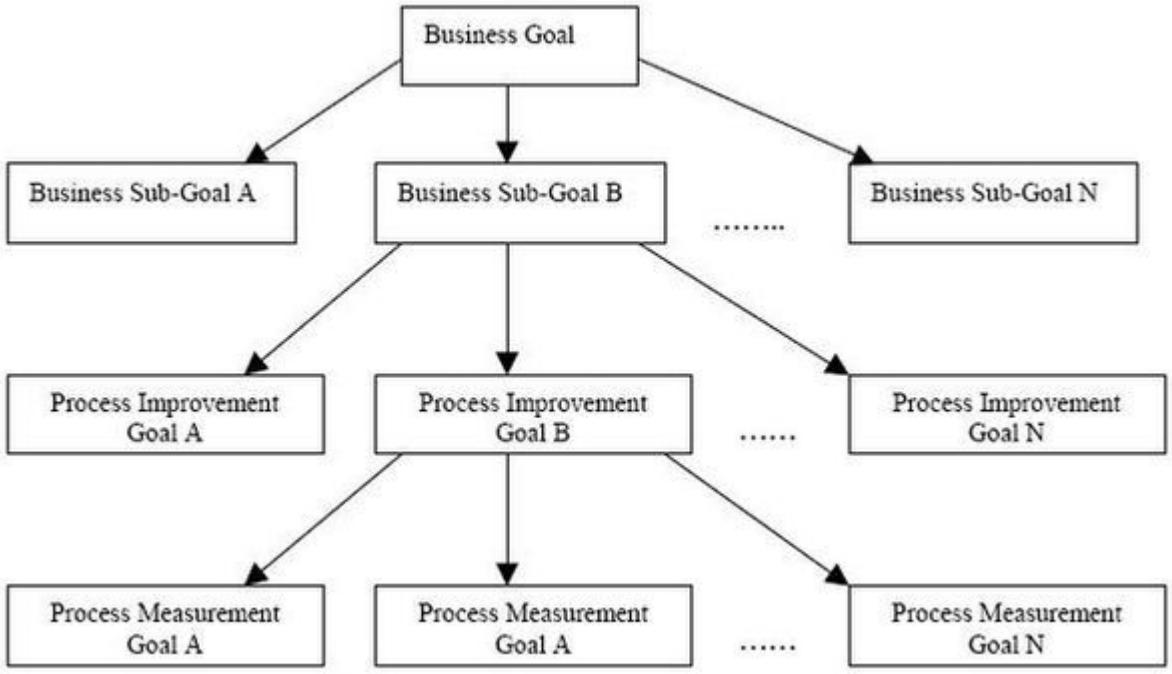

Figure 2: Decomposing goals into sub-goals

GOALS-QUESTIONS-METRICS FOR SI

Table 1 shows the typical characteristics/features of an innovation process. The characteristics serve as goals of innovation, are derived from best practices of innovation listed in different literatures. We do not claim that the characteristics that we list in Table 1 exclusively cover all aspects of any innovation project. We have listed only nine characteristics that we believe are important for any innovation effort. However, while using this framework in an actual project setting, we recommend revising this list of characteristics based on the nature and importance of the business/organizational goals, and innovation efforts being conducted.

Table 2 (a –f) shows the metrics that can be used in a typical innovation project. These metrics are derived using the GQM methodology. Thus, in this goal-driven innovation process measurement framework, the innovation process measurement goals are refined by questions that may lead to the assessment of innovation successes. These goals are then followed by the definition of suitable metrics that make it possible to answer the corresponding question. The goals-questions-metrics combination for an innovation project is termed as the goal-driven measurement plan for innovation. Table 2 shows the goals-questions-metrics for a typical SI project.

The goals that are listed in Table 1 are collected based on the key innovation process characteristics and best practices identified in existing innovation literatures. Similarly, the questions and metrics listed in Table 1 are primarily for exemplifying the approach. With the help of Table 1, the exact set of goals, questions, and metrics usable for a particular SI project should be defined taking the requirements and scope of the project into consideration.

Table 1: Innovation characteristics/features that should typically be taken into consideration in a project.

	Characteristics/Features
1	Innovation program: identification of lifecycle, processes, planning and implementation
2	Innovation frameworks: development of baseline and target product artifacts
3	Business alignment: alignment with business objectives and priorities
4	Involvement of senior management
5	Participation of operating units
6	Innovation-related communication, awareness and training
7	Innovation governance
8	Cross-functional teams for innovation
9	Project management structures

Table 2a: Goals-questions-metrics for a typical SI project.

SI Goal(s)	SI Question(s)	SI Metric(s)
Innovation program: identification of lifecycle, processes, planning and implementation	Does the innovation program have a lifecycle that should be adhered to in the program? How effective is it?	Number of lifecycles process, product, etc.).
		Number of cases where the chosen lifecycle was proven to be effective in reducing product delivery time.
		Number of cases where the chosen lifecycle was proven to be effective in reducing product delivery costs.
		Percentage planning time spent on choosing the appropriate lifecycles.
	To what extent does the innovation process comply with corporate, industry standards guidelines?	Degree of referral of the process model to standards = (Number of standards referred to while designing the innovation process) / (The number of standards available in the area).
		Extent of reference to standards = (Number of references made in the innovation process manual / (Total number of references found in the innovation process manual).
	How much is the innovation program value driven?	Percentage of unique value considerations of the proposed innovation program.
		Percentage of cases where the innovation program was found to have value.
	How much agile/adaptive is the innovation program?	Percentage of cases where the innovation program was found to be agile/adaptive.

Table 2b: Goals-questions-metrics for a typical SI project.

SI Goal(s)	SI Question(s)	SI Metric(s)
Innovation frameworks: development of baseline and target product artifacts	Does the innovation framework identify the baseline and target product artifacts?	Total number of baseline product artifacts.
		Total number of target product artifacts.
		Ratio of baseline to target products artifacts.
	Does the innovation framework identify the baseline and target process artifact?	Total number of baseline process artifacts.
		Total number of target process artifacts.
		Ratio of baseline to target process artifacts.
	Does there exist product and process artifact lifecycle?	Number of product artifact lifecycles.
		Number of process artifact lifecycles.
	Is there any documentation related to innovation maintained?	Density of product documents = Number of printed pages of innovation related documents available per product developed per step of the product lifecycle.
		Density of process documents = Number of printed pages of innovation related documents available per product developed per step of the process lifecycle.
Business alignment: alignment with business objectives and priorities	To what extent is the innovation process top-down and business driven?	Number of business goals analyzed in the *first* step ("market findings / requirements") of the innovation process.
		Extent to which each step of the innovation process is top-down = Number of unique actions undertaken in that step per unique goal of the previous step.
	How effective is the innovation process to identify potential threats and risks?	Average number of threats/risks detected per step of the innovation process.
	How much are the innovation investments guided by business goals?	Average investment per business goal.
		Number of cases in which business goals were taken into consideration for innovation investment planning.

Table 2c: Goals-questions-metrics for a typical SI project

SI Goal(s)	SI Question(s)	SI Metric(s)
Involvement of senior management	Are the senior managers well aware of the pros and cons of innovation?	Number of cases where the senior managers were not aware of the pros and cons of innovation.
		Number of cases where the senior managers were aware of the pros and cons of innovation.
		Percentage senior managers involved (or are supposed to be involved) who were found to be knowledgeable of the pros and cons of innovation.
	Are the senior managers supportive of the innovation efforts?	Number of cases where the senior managers were not supportive of the innovation efforts.
		Number of cases where the senior managers were supportive of the innovation efforts.
		Percentage senior managers involved (or are supposed to be involved) who were found to be supportive of the innovation efforts.
	Are the senior managers participative in the innovation efforts?	Number of cases where the senior managers participated in the innovation efforts.
Participation of operating units	Are the operating units aware of the pros and cons of innovation?	Number of cases where the operating units' personnel were not aware of the pros and cons of innovation.
		Number of cases where the operating units' personnel were aware of the pros and cons of innovation.
		Percentage operating units' personnel involved (or are supposed to be involved) who were found to be knowledgeable of the pros and cons of innovation.
	Are the operating units supportive of the innovation efforts?	Number of cases where the operating units' personnel were not supportive of the innovation efforts.
		Number of cases where the operating units' personnel were supportive of the innovation efforts.
		Percentage operating units' personnel involved (or are supposed to be involved) who were found to be supportive of the innovation efforts.
	Are the operating units participative in the innovation efforts?	Number of cases where the operating units' personnel participated in the innovation efforts.
		Number of cases where the operating units' personnel participated in the innovation efforts.
		Percentage operating units' personnel involved (or are supposed to be involved) who participated in the innovation efforts.

Table 2d: Goals-questions-metrics for a typical SI project.

SI Goal(s)	SI Question(s)	SI Metric(s)
Innovation-related communication, awareness and training	Is there a communication program? If so, how effective is it?	Number of staffs (of all kinds that have a stake in the innovation program) involved in the communication program.
		Number of personnel who are dedicated for participating in the communication program.
		Percentage cases where the communication personnel directly helped in the innovation program.
		Ratio of communication program investments to innovation investments.
	Is there an awareness program? If so, how effective is it?	Number of staffs (of all kinds that have a stake in the innovation program) involved in the communication program.
		Number of personnel who are dedicated for participating in the communication program.
		Percentage cases where the communication personnel directly helped in the innovation program.
		Ratio of investments related to innovation awareness to innovation investments.
	Is there a training program? If so, how effective is it?	Number of staffs (of all kinds that have a stake in the innovation program) involved in the training program.
		Number of personnel who are dedicated for participating in the training program.
		Percentage cases where the training helped in the innovation program.
		Ratio of training investments to innovation investments.

Table 2e: Goals-questions-metrics for a typical SI project.

SI Goal(s)	SI Question(s)	SI Metric(s)
Innovation governance	Is there a distinct governance body for innovation? How effective is the body?	Percentage of personnel that are dedicated for the governance of innovation.
		Percentage of other personnel who assist the personnel directly involved in the governance.
		Percentage cases where the dedicated governance body helped in the innovation efforts.
		Ratio of investments made for the establishment and the operation of the governance body to the total innovation investments.
	How is the relationship of the governance body members with the other operating groups associated with innovation?	Number of cases where the governance body members and the other operating groups' personnel worked together to resolve an issue.
		Number of cases where the advice of governance personnel directly benefited the operating groups.
		Number of cases where the advice of governance personnel directly benefited the operating groups.
		Percentage of total time spent by the governance body and the operating members, on discussing innovation activities to the total duration of the innovation program.
	How effective is the governance body to ensure that all standards are adhered to in the innovation efforts.	Total number of cases where the governance body found adherence to standards.
		Total number of cases where the governance body found non-adherence to standards.
		Percentage of total time spent by the governance body and the operating members, on discussing innovation activities to the total duration of the innovation program.

Table 2f: Goals-questions-metrics for a typical SI project.

SI Goal(s)	SI Question(s)	SI Metric(s)
Cross-functional teams for innovation	Are different functional perspectives taken into consideration for innovation?	Percentage of total time spent on taking different cross-functional perspectives into consideration.
		Percentage cases where cross-functional perspectives proved to be useful.
	Are there effective team building programs? How effective are they to ensure that the cross-functional teams work effectively?	Number of team-building activities.
		Percentage of total time spent on team-building activities.
		Number of cases where the team building activities were found to be effective.
	Are the teams capable of solving cross-functional problems? How effective are they?	Number of cases where the teams successfully solved the cross-functional problems amongst themselves.
		Number of cases where the teams successfully solved the cross-functional problems with the help of senior management.
		Percentage of total time spent by teams on solving cross-functional issues that is found to be useful.
Project management structures	Are the project management approaches and the corresponding structures identified? How effective are they?	Percentage of total time spent on identifying the project management approach and structure.
		Number of cases where the choices of the chosen project management approach and structure were found to aid in resolving issues.
	Is the project management structure aligned with the innovation efforts?	Number of cases where the chosen project management structure was determined to be useful in resolving innovation issues.
		Percentage of project planning time spent on analyzing whether the project management structure is aligned with the innovation effort.

ROADMAP FOR IMPLEMENTATION

The implementation of the proposed goal-driven measurement framework for SI process consists of the following four main steps as shown in Figure 3: Define Measures, Analyze Process Gaps, Define/Refine Action Plans, Define/Refine Process Improvement Goals.

The implementation of the framework is based on the notion of *continuous improvement* of the innovation processes. The first step in measuring the SI process is defining the measures that are used to assess and control the SI process. As discussed before, the measures are translated from the top-level business goals that act as the primary drivers in innovation. The rationale behind connecting the innovation goals with the business goals is that it is quite likely that innovation activities that are not linked to the business strategies would quite likely not receive the full organizational support, and would quite likely fail.

The next step in the implementation of the framework is *collecting the measurement data* using the defined measures, and then analyzing the gaps that exist between the current innovation processes and the targeted processes. This is typically done by designing questionnaires, performing surveys, and conducting interviews. The strengths, weaknesses, problems, and root causes of the current processes are analyzed and documented in this step. These aspects are analyzed along with the process improvement goals, and a new action plan is defined (or an existing plan is refined). This action plan is then used to circumvent the innovation process gaps that are determined, and the process improvement goals are analyzed and refined. Based on the results that are obtained, the GQM methodology is used to modify the existing goals, questions, and metrics.

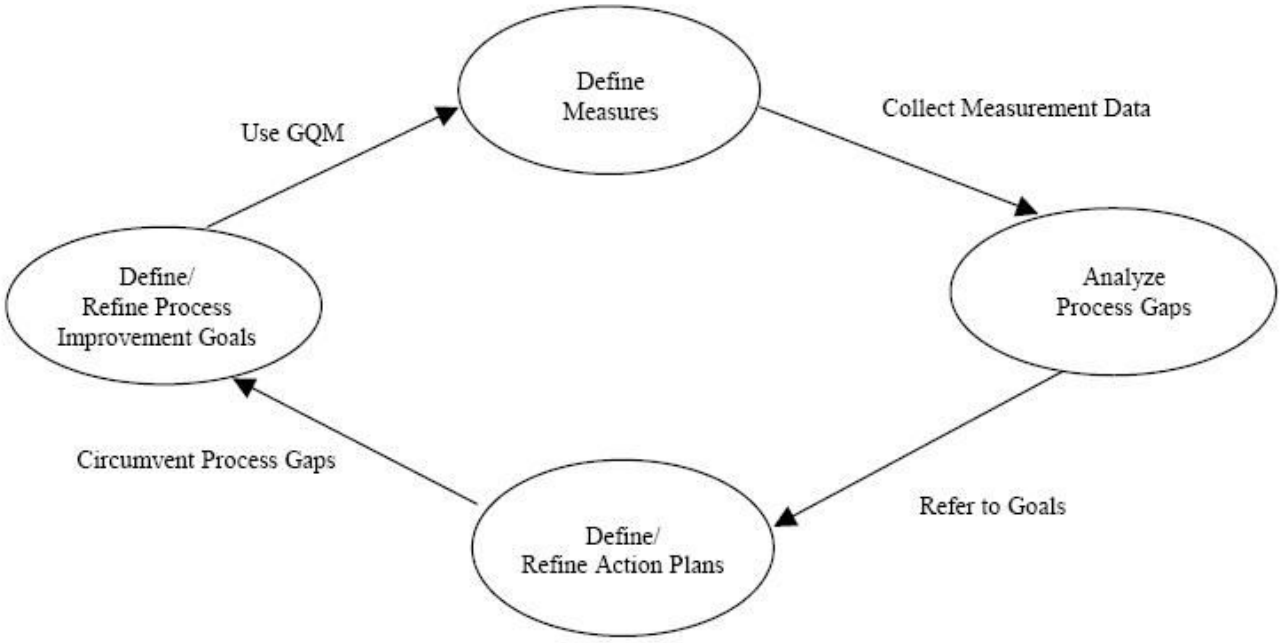

Figure 3: Roadmap for implementation of the framework

CONCLUSIONS

In this paper we provided a goal-driven framework for measuring the SI process. The key contributions in this paper are the identification of the different steps constituting the framework, the identification of innovation goals in a typical SI process, and most importantly, identifying the metrics that aid in measuring the different aspects of the SI process.

REFERENCES

[1] Basili, V.R. and Rombach, H.D., "The TAME project: towards improvement-oriented software environments", *IEEE Transactions on Software Engineering*, Vol. 14, No. 6, June 1988, pp. 758-773.

[2] Basili, V.R., Caldiera, G. and Rombach, H.D., "Goal question metric paradigm", *Encyclopedia of Software Engineering*, John Wiley and Sons, New York, 1994, pp. 528-532.

[3] Carneiro, A., "How does knowledge management influence innovation and competitiveness?", *Journal of Knowledge Management*, Vol. 4, No. 2, 2000, pp. 87-98.

[4] Cagan, J. and Vogel, C.M., *Creating Breakthrough Products*, Prentice Hall, New Jersey, 2002.

[5] Goethert, W. and Hayes, W., *Experiences in implementing measurement programs*, Technical Report, CMU/SEI-2001-TN-026, Software Engineering Institute, Carnegie Mellon University, November 2001.

[6] Kakola, T., "Software Business Models and Contexts for Software Innovation: Key Areas for Software Business Research", *Proceedings of the 36th Hawaii International Conference on System Sciences* (*HICSS'03*), Big Island, Hawaii, USA, 2003.

[7] Kline, S.J. and Rosenberg, N. "An overview of innovation", *Positive Sum Strategy: Harnessing Technology for Economic Growth*, National Academy of Science Press, 1986.

[8] Komi-Sirvio, S., Oivo, M. and Seppanen, V., "Experiences from practical software process improvement", *Proceedings of the European Software Improvement Conference (EuroSPI),* Gothenburg, 1998.

[9] Cucza, T., *Knowledge management process model*, Technical Report, VTT Publications, Technical Research Centre of Finland, 2001.

[10] Kumar, V., Mathur S. and Kumar, U., "An overview of the innovation process in the Canadian electronic and telecommunication (E&T) industry", *Engineering Management Journal*, Vol. 6, No. 3, 1994, pp. 23-30.

[11] Kurdi, S., *Software development process and strategies used to expedite software development*, MMS Thesis, Eric Sprott School of Business, Carleton University, Ottawa.

[12] Maria, T. and Giuseppe, V. "Empirical investigation on the innovation diffiusion in a software development process", *International Journal of Software Engineering and Knowledge Engineering*, Vol. 9, No. 5, 1999, pp. 595-621.

[13] Nahar, N., Kakola, T. and Huda, N., "Diffusion of software technology innovations in the global context", *Proceedings of the Hawaii International Conference on System Sciences*, Big Island, Hawaii, 2002.

[14] Park, R.E., Goethert, W.B., Florac, W.A., *Goal driven software measurement – a guidebook*, Technical Report, CMU/SEI-96-HB-002, Software Engineering Institute, Carnegie Mellon University, August 1996.

[15] Parviainen, P., Oivo M. and Vayrynen, K., "From goal definition to experience packaging: industrial experiences of a GQM-based measurement program, *Proceedings of ESCOM-SCOPE'99*, East Sussex, U.K., 1999.

[16] Rehman, T.U., Nafees, S., Khiyal, S.H. and Mahmood, Z., "A Goal/Question/Metrics based technique for implementing requirements management key process area", *Proceedings of the Software Quality Management Conference (SQM 2002)*, Glasgow, 2002.

[17] Rombach, H.D. and Ulery, B.T., "Improving software maintenance through measurement", *Proceedings of the IEEE*, Vol. 77, No. 4, April 1989, pp. 581-595.

[18] Saren, M.A., "A classification and review of the intra firm innovation process", *R&D Management*, Vol. 14, No. 1, 1984, pp. 11-24.

[19] Solingen, R.v. and Berghout, E., *The Goal/Question/Metric method: a practical guide for quality improvement of software development*, McGraw Hill, London, 1999.

[20] Soulder, W.E., *Managing new product innovations*, Toronto D.C. Health and Company.

AUTHORS BIOGRAPHY

Subhas C. Misra held several positions in several organizations including Senior Project Advisor in Super Net Solutions, Scarborough, Ontario, Canada, Software Developer in Nortel Networks, Ottawa, Canada, and Assistant Executive Engineer in the Indian Telephone Industries, Mankapur, India. He has several years of experience working on R&D projects in software engineering, project management, quality engineering, risk management, and project management. He has published several technical papers in different international journals, and is a regular speaker in reputed conferences. He has also offered several tutorials in the allied areas. Subhas received several prestigious academic awards that include

Best Paper Award for one of his published papers. He received his M.Tech. degree in Computer Science and Data Processing from the Indian Institute of Technology (IIT), Kharagpur, India, and M.S. in Computer Science from the University of New Brunswick, Fredericton, Canada. He is also completing his PhD in Information Technology Management from the Eric Sprott School of Business, Carleton University, Canada.

Vinod Kumar Ph.D., received his graduate education from the University of California, Berkeley and the University of Manitoba. He has been the Director of the Sprott School of Business - Carleton University for ten years and is currently the head of the Manufacturing Systems Centre- an organized research unit at Carleton. He is a professor of Technology and Operations Management. Before joining academia in the early eighties, Dr. Kumar worked for manufacturing industries for over 15 years in India, the U.S. and Canada in various line and staff management positions. He is a member of a number of professional organizations. Dr. Kumar's research is in enterprise system adoption and implementation, e-commerce technology strategy, supply chain management, improving performance of production and operation systems, manufacturing flexibility, technology transfer, quality in R&D, and innovation management in defence and high tech sector. Dr. Kumar has published over 120 articles in refereed journals and proceedings. He has won several Best Paper Awards in prestigious conferences. Dr. Kumar has also obtained the Scholarly Achievement Award of Carleton University for the academic years 1985-86 and 1987-88 and Research Achievement Award for the year 1993 and 2001. He is on the editorial board of two International Journals. In addition, Dr. Kumar has also served for several years on the Board of Governors and the Senate for Carleton University and on the Board of the Ontario Network of e-Commerce.

Uma Kumar M.Sc., M.S., Ph.D. is a Full Professor of Management Science and Technology Management and Director of the Research Centre for Technology Management at Carleton University. She has been the Director of Graduate Programs of the Eric Sprott School of Business at Carleton University. Dr. Kumar's research is in the area of Management of Technology including forecasting and monitoring technology, efficiency in new product development through e-commerce, quality in R&D, managing R&D internationally, R&D and innovation policy, performance metrics in e-commerce, and ERP adoption and implementation. Dr. Kumar has published over 90 articles in journals and refereed proceedings. Her eight papers have won best paper awards at prestigious conferences. She has won Carleton's prestigious Research Achievement Award and twice, the Scholarly Achievement Award. Dr. Kumar is the recipient of a number of research grants from reputed research funding agencies.

Rajendra P. Mishra received the B. Eng., PGDM degree. He is a member of the Institution of Electrical Engineers, United Kingdom. He worked for many years in manufacturing industry. Currently, he is a full-time Ph.D. student at Sprott School of Business, Carleton University, Canada. His research focuses on information system, e-commerce, supply chain management, and product development.