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Procedia Computer Science 16 (2013) 786 – 795

Procedia
Computer Science

Conference on Systems Engineering Research (CSER'13)
Eds.: C.J.J. Paredis, C. Bishop, D. Bodner, Georgia Institute of Technology, Atlanta, GA, March 19-22, 2013.

An approach to understand and elicit requirements using systemic models: Ensuring a connect from problem context to requirements

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Abstract

The context in which Businesses operate today is becoming increasingly complex. This is due to the influence of the various factors such as societal, political, economical, regulatory, cultural, and technological on the business. For IT organizations focusing on next generation systems, the ability to understand and cope with this complexity is needed to elicit correct business requirements to build effective solutions. Research studies have highlighted "requirements creep and gaps" to be a major cause of many software systems problems. The inability to comprehend these business systems leads to a lot of rework at later stages including shelving of the projects in some scenarios. Research carried out in our lab to address this problem, led to the design of an approach that begins with the big picture understanding of the business, identifies suitable business objectives which are traced to business processes for realization and elicits corresponding requirements. It comprises multiple models which include a qualitative cybernetic model to understand the context with all its influences and a stakeholder model to derive the business objectives based on stakeholder perspective. The paper outlines the approach encapsulated in a methodology to establish connect from the business context to the elicited requirements for solution development along with a case illustration.

Selection and/or peer-review under responsibility of Georgia Institute of Technology

Keywords: complex systems; big picture; business requirements; cybernetics; business objectives; stakeholder analyses; requirements traceability

1. Introduction

Information Technology (IT) service organizations are required to develop software solutions for various projects ranging from simple to overly complex and gigantic ones. These projects may include business contexts, problems associated with such business contexts, needs of the business context, or any other task needing a software solution. Such projects are needed to be understood holistically from a plurality of vantage points. There are many models to address various touch points across the software development life cycle. These typically start with the requirement gathering phase and techniques [1,2] such as questionnaires, workshops, cause and effect diagrams, flowcharts, and algorithms of important aspects of the projects are used in order to understand the project and elicit requirements.

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1877-0509
Selection and/or peer-review under responsibility of Georgia Institute of Technology
doi:10.1016/j.procs.2013.01.082

While these methods help in capturing a lot of data, comprehending and representing this data into appropriate models which will help in analysis and translation of this information to the next level of solutioning is a challenge. This results in gaps in requirements which cascade down the line and result in software failures [3]. Studies reveal that 30- 40% of software defects can be traced to gaps or errors in requirements [4]. One of the prime reasons attributed has been in understanding the context of the business. Another reason could be while the context is understood, the difficulty in translating that understanding into correct business and software requirements. In the current business scenario the client expects service providers not just to play the role of an IT vendor but a partner who understands their business and contributes value through the solutions built. Hence it is essential to build solutions which reflect a right understanding of the current business needs and can also accommodate the emerging needs which make the solution sustainable.

Systems science methodologies [5,6,7,8] provide a way to address complex problems, while taking into account the big picture and context of such problems. They are useful for making implicit assumptions about complex phenomena explicit, which exposes gaps in knowledge about the problem. Hence these models and principles [9] can effectively be leveraged to address the concerns of understanding the context of business for building an IT system and building the bridge to IT solution design from business purpose.

The methodology presented in this has been developed from the synthesis of different systemic models from the field of management sciences, system sciences, cybernetics and software engineering. The framework integrates multiple models to define the system in focus from a larger perspective, identifying the key players or stakeholders of the system, their needs from a systemic perspective, formulating objectives to be fulfilled for the overall system and defining the required processes and requirements. This approach ensures a trace right from the problem context to the IT requirements. The paper has been organized as follows: Section 2 outlines the approach encapsulated in a broad methodology Section 3 covers an application of the methodology to a case and Section 4 concludes with the benefits and the way forward.

2. The Methodology

The approach was developed based on a systemic approach, which recognizes the non linear behavior of business systems. It also systemically ensures traceability from the initial context understanding to the software requirements. This ensures two fundamental aspects of an effective solution design, primarily understanding the context correctly; next ensuring it has been encapsulated into the software requirements. Understanding the Context includes the stakeholder’s perspective and the environment which influences or is influenced by the proposed solution for the system. This understanding is traced through other models for completing the requirements capture.
The key models in this methodology [10] are: defining the System in Focus, Qualitative Cybernetic Model, Stakeholder Analysis Framework, Objective alignment model and Process Requirement Matrix as depicted in Fig 1.

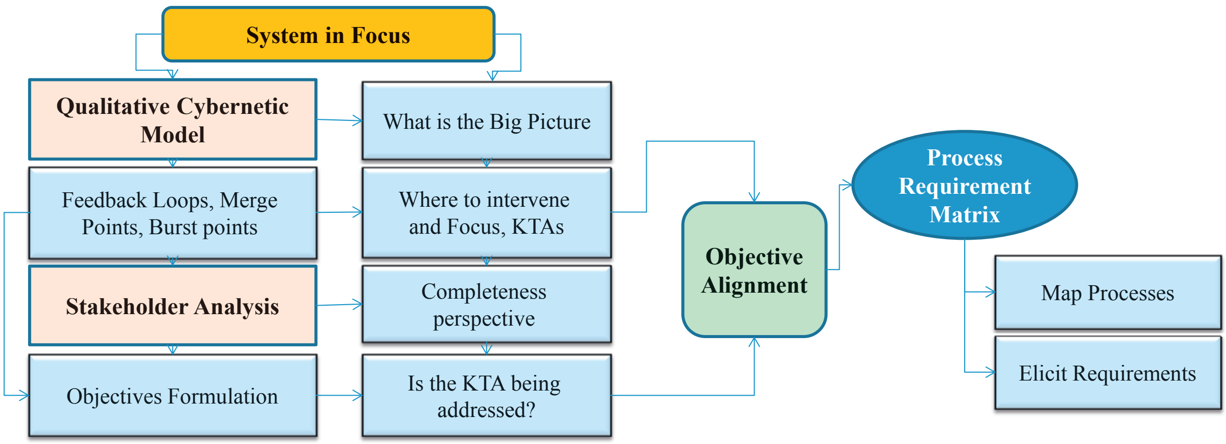

Fig. 1. Overview of the Methodology

2.1. System in Focus

In this methodology, the first step is definition of the system in focus (SIF) which identifies the overall purpose, scope and boundary by analyzing the supra system. This system definition [6,7] helps us to view the business context from a systems thinking perspective. The business we are trying to address exists in an environment. In order to address its problem we need to understand the influence from the environment and also and influence from within. This boundary of the business with its key influences forms the SIF. The SIF exists in the wider system of which it is a part. The SIF itself consists of several subsystems.

The following method is adopted to define the SIF:

- Identify the Purpose of the system and define the scope of the system being solutioned.
- Identify the Supra system to which the target system belongs. This would comprise broadly the societal, political, economical, regulatory, cultural, technological systems. E.g. A banking system is part of larger financial, social and regulatory environment.
- Identify subsystems which are part of the system in focus.
- Identify the relevant stakeholders: identify those for whom the solution is being designed and those who critically influence or get influenced by its functioning.
- Define the boundary with respect to what/ who is IN and OUT side the scope of the proposed system.

2.2. Qualitative Cybernetics Model

Popular models exist in system engineering and system dynamic fields to understand, visually depict and analyze the business information. These include system dynamics [11], which proposes Causal Loop Diagrams, a quantitative model which helps to understand the system and simulate its behaviour. As part of the Soft systems methodology [12], Rich Pictures provide a mechanism for learning about complex or ill-defined problems by drawing detailed ("rich") representations of them. Gharajedhagi [6] dealt with the concept of understanding the system as a whole and has proposed an iterative process of Inquiry for understanding complexity using the Systems Thinking approach. Peter Senge [13] has analyzed the systems archetypes which describe common patterns of behavior in organizations. As diagnostic tools they provide insight into the underlying structures from which behavior over time and discreet events emerge.

Even though there are several quantitative and qualitative models to understand different dimensions of a system, given the urgency of building solutions in an IT scenario, applying these models is a challenge due to the enormous amount of data and modeling required. While some models overcome these limitations, guidance to interpret and analyze the model is limited.

The proposed Qualitative Cybernetic Model, CID™ [14, 15, 16] has been constructed taking the best primitives from some of these models and synchronizing the cybernetic concepts. This is a qualitative abstraction of the "system in focus" we are trying to understand in the form of a diagram. It captures the inherent cybernetic concepts of communication, control and non linear behavior contained in a system. It provides guidance to interpret and analyze the system in focus and identify the key focus areas to be incorporated into the solution design.

Cybernetic Influence Diagram, CID™:

This Model is drawn based on a preliminary understanding of the situation under study with all the relevant empirical and theoretical information collected. The diagram depicts a collection of elements and influences between them. This representation helps the modelers to reflect on or refine their ideas regarding the problem situation. It guides careful problem construction through broadening of issues until they can be explained. CID™ [Refer Fig 2] can be visually depicted by having key elements as nodes and the relationships among the key elements as directed links. Each link represented by arrow from one element to another represents a proposition. The direction of the link depicts a relationship like 'causes', 'influences', 'leads to', 'inheres', 'decreases' etc. The translation of all propositional relationships into arrow-links produces a set of interconnected and interacting feedback cycles.

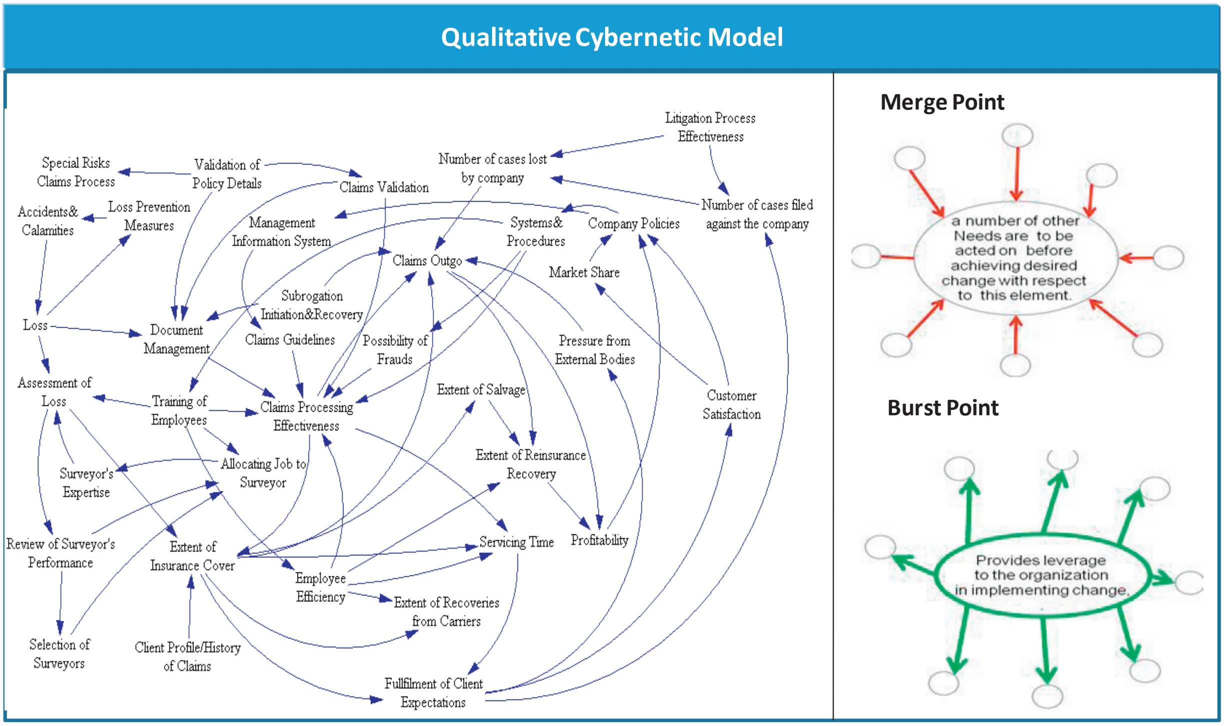

Fig 2. Qualitative Cybernetic Model: CID™

This CID™ representation throws up different types of patterns for analysis – feedback loops, merge and burst points. Starting from any element, if the direction of influence is traced and it leads back to the same element, it is a feedback loop. Identifying feedback loops in the CID™ gives insights into pain areas in the system. The length of a loop signifies a delay, which can reduce the efforts of the system to change quickly. When a significant number of arrows merge to a single point, it is termed a merge point or a sink. Similarly where a significant number of arrows emerge from a point, it is called a burst or source point. A merge point typically signifies an objective to be fulfilled and a burst point signifies an objective that can be leveraged to bring about the change. Both merge and burst points signify the focus areas to be addressed in the solution, hence are called as Key Thrust Areas (KTAs). These KTAs have to be addressed in solution design as key business requirements of the system.

2.3. Stakeholder Analysis Model

The concept of Stakeholders has been addressed through several models in different disciplines. Warfield [17] has proposed dealing with people concerns in developing potential solutions, has portioned them into three groups: stakeholders – the people who have a stake in the issue being considered; content specialist - people who have specialized knowledge that is relevant to the SIF; structural modelers –whose task is to structure the issue being considered. Weber [18] has classified the stakeholders as per their scope of interest and influence.

For the purpose of this methodology, we have constructed a stakeholder framework SNAC™ (Refer Fig 3) integrating Warfield's stake holder concept, the Unified program Planning approach and Weber's Stakeholder influence grid leading to formulation of business objectives of the system in focus. SNAC™ is an acronym for Stakeholders, their Needs, the system factors, which can be Altered and Constraints, which come in the way of fulfilling the needs. SNAC analysis is used to generate a comprehensive and exhaustive set of objectives for the SIF.

The general form of the Objective is: *Infinitive Verb + Object of infinitive + Qualifying phrase or constraint*

To is the infinitive generally used. Ex: To + optimize + customer related procedures.

•<u>Stakeholders:</u> Those who have an interest (or stake) in the operation and performance of the organization. They may or may not be in a position to influence the organization directly.
•<u>Needs:</u> The needs each stakeholder group seeks to fulfill through the (System in Focus) organization.
•<u>Alterables:</u> These are the things the organization believes it can alter or change to fulfill the need.
•<u>Constraints:</u> These are the things the organization believes it cannot change.
•<u>Objectives:</u> Objectives are surrogates for value, by clearing stating Objectives it becomes possible to explore the desired and also to operationalize it. These objectives are required to be realized by the solution.

Fig. 3 Stakeholder Analysis Model

These objectives are developed based on the criteria that each objective satisfies Needs of the Stakeholders either by overcoming a Constraint or by changing an Alterable.

2.4. Objective Alignment Model

In the Objective Alignment framework, the KTAs derived from the cybernetic model and Objectives derived from stakeholder framework are aligned and validated using a traceability matrix as shown in Fig 4. This matrix ensures systemic alignment and trace between the CID™ and stakeholder framework.

	KTAs			
OBJECTIVES	KTA-1	KTA-2	…...	KTA-n
Objective-1	X			X
Objective-2		X		X
Objective-3	X			
Objective-n		X		

Fig. 4: KTA - Objective Mapping Matrix

This Alignment leads to:

- Identification of gaps if any in the objectives required for realizing the system objectives
- Identification of focus areas which may be missed out while detailing the CID™ and are important from stakeholder perspective.
- The congruence between the two leads to a systemic solution keeping in view the needs from the environment and stakeholder perspective.

2.5. Process Requirement Matrix

The systemic models discussed so far have helped formulate and validate the requisite business objectives for the System in Focus. Process is the primary vehicle to fulfill these objectives [6]. Besides processes, the organization can have other capabilities to realize in terms of products, specific people competencies, initiatives etc. Literature and models [19, 20] highlight the importance of linking the stakeholder perspective and context to the business process definition. This step in the methodology leads to identification of gaps if any in terms of the processes for delivering the objectives or redundancy of processes in the organization. The objectives which are derived from a stakeholder perspective ensure the needs from a completeness perspective. The next step is to see if there are processes or capabilities in the organization which lead to this fulfillment. As depicted in Fig 5, we identify the processes and other capabilities [21, 22], which help in realizing the objectives derived and aligned in earlier steps.

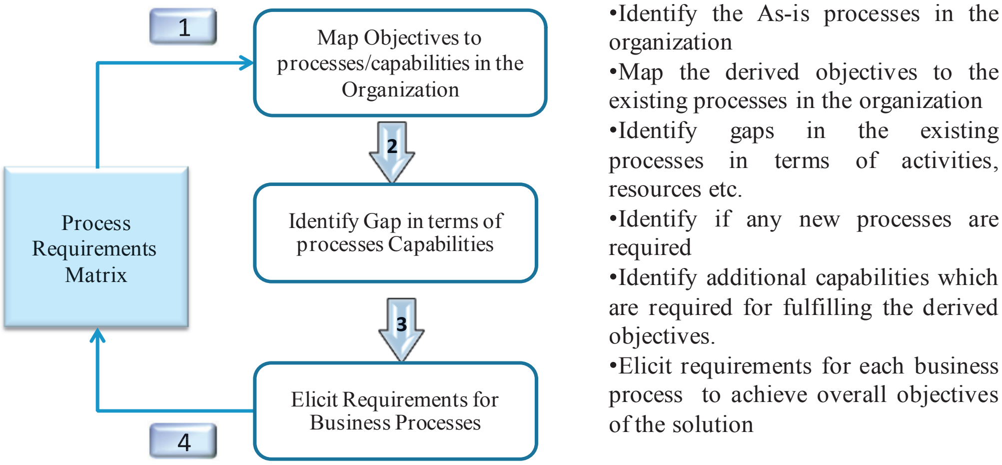

Fig. 5: Process – Requirement Matrix

An objective – process – requirement matrix is created to ensure connect of requirements to the processes and objectives. This alignment and validation of requirements ensures the traceability across all the models [11].

3. Case Study

3.1. System in Focus

We have taken a business system developed for a Tata Consultancy Services (TCS) internal initiative at a conceptual level for illustrating the methodology. "Graduate Recruitment and Development" GRD is an unique initiative which was started with an intent to transform young science graduates from smaller cities and towns into software professionals. This would help the organization to reduce attrition and also help develop a pool from the graduate eco system. The challenge for TCS was the environment was relatively new in terms of the profile of the colleges they were to connect to, the students, the societal value system etc. The TCS unit "GRD" as an organization was to take up the end to end responsibility from recruitment to training to deployment. As a sourcing–training-deployment value chain, an entire ecosystem of stakeholders, performing diverse functions invoking multiple support systems were involved. In order to achieve order of magnitude improvements, the entire business process chain was to be digitized. This is in brief the background.
Fig 6 depicts the system in focus with the key stakeholders and subsystems involved.

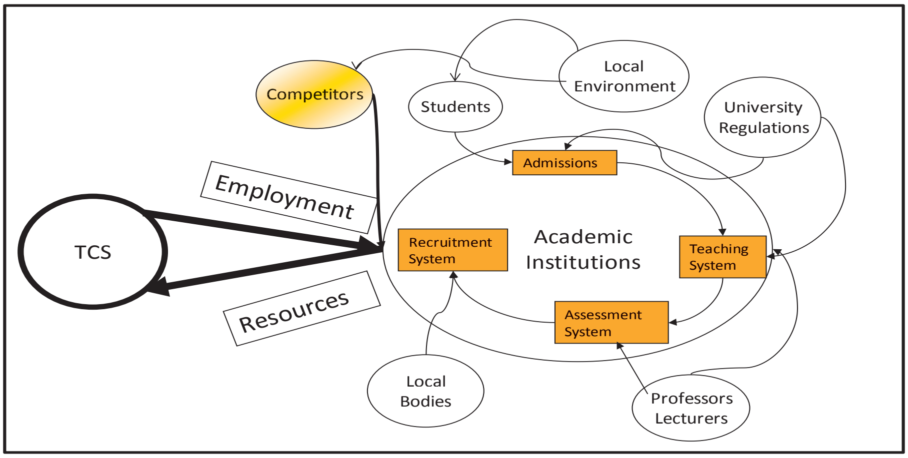

Fig. 6: TCS Graduate Recruitment and Development – System In Focus

3.2. Cybernetic Influence Diagram

Based on the understanding of the SIF and its environment, the qualitative cybernetic model – CID was drawn. A partial illustration of the CID is depicted in Fig 7 below. An analysis of the CID led to the identification of the Merge and Burst points.

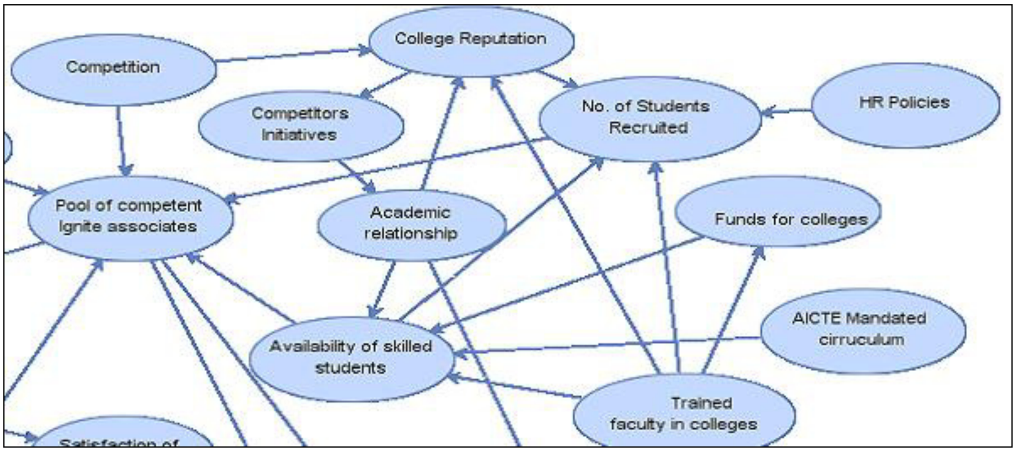

Fig. 7: Graduate Recruitment System - CID

The KTAs were derived from the CID merge and burst points and were further validated with the SMEs (Subject Matter Expert). Some of the identified KTAs of the SIF, i.e. the graduate recruitment eco system were: Quality of training, Innovative training methods, Availability of skilled students, Allocation to Projects, Academic Relationship, Interface between SIF and Projects, Collage Reputation, Number of Students Recruited

3.3. Stakeholder Analysis

The key stakeholders after an analyses of the SIF were TCS, Students, Colleges, College Faculty, TCS Unit Management, TCS Faculty, TCS Projects. The other stakeholders who influenced the SIF included the parents of the graduate students, the local governments, the professors of the institutions, the local employers etc. Based on the Stakeholder analysis outlined in Fig 3, the needs for the stakeholder were arrived at. Further there was a listing of constraints and a derivation of the alterable. From theses four parameters, a list of objectives was formulated. Below is a representative set of SNAC [Table 1] and a list of objectives derived thereof:

Table 1. Illustration of Stakeholder Analysis

Stakeholders	**Needs**	**Constraints**	**Alterables**
TCS GRD	Building IT Professionals base of under graduates from small cities To ensure long term commitment from associates Availability of trained resources for the projects Sustain Growth during economic downturn Good relationships with academic institution To build and offer relevant training to students To reduce the time and cost of training To include industry specific vocational courses in curriculum	Local bodies influence over recruitment process Student's limited exposure Current syllabus of AICTE Competition Longer training Times Faculty willingness to teach industry oriented courses	New Infrastructure developments for Training & Development Employee friendly HR policies to attract the best of the talent Establishment of network with local bodies and colleges Inward sabbaticals for Faculty Equal employment opportunity Student e-learning modules and access to current technology areas Industry specific vocational courses in curriculum Sensitive HR processes to address Parents concerns
Students	Good Job opportunity and identity with a good company Better prospects and social status Good facilities and training on latest technologies Regular communication on joining / training programs	Lack of employment opportunities Programming / Software skills Infrastructure at collages Parent's resistance to send children outside for employment	

Objectives:

- To establish new training facility and program tailored for recruited undergraduates from smaller cities
- To establish sensitive HR processes to address local student needs
- To establish network with local bodies and colleges for smooth recruitment process
- To provide inward sabbaticals for faculty for motivation and skill upgrades
- To introduce industry specific vocational courses at colleges to increase exposure

3.4. Objective Alignment Model

The KTAs identified above from the CID and the Objectives derived from stakeholder analysis were aligned and traced against each other. Table 2 shows an illustration of the objective alignment to KTA. This led to identifying some of the gaps in terms of key objectives and thrust areas.

Table 2 Illustration of Objective – KTA Alignment

	KTAs				
OBJECTIVES	Quality of training	Innovative training methods	Recruitment Process	Local Environment	Academic Relationship
To establish new training facility and program tailored for recruited undergraduates from smaller cities	X	X			
To establish sensitive HR processes to address local student needs			X	X	
To have academic industry liason			X		X
To provide inward sabbaticals for faculty for motivation and skill upgrades					X
To introduce industry specific vocational courses at colleges to increase exposure		X			X
To establish network with local bodies for smooth recruitment process			X	X	

3.5. Process Requirement Matrix

The processes for the SIF lifecycle span both the supply side (academic ecosystem) and the demand side (customer ecosystem). In this stage, the objectives were mapped to the processes and the gaps in the processes or capabilities are identified. Below is an illustration of tracing of one objective to corresponding processes.

Objective: To establish new training facility and training program tailored for recruited undergraduates from smaller cities
Objectives to Process mapping: Processes which will ensure realization of the objective

Identify training facility
Create an inspiring training zone
Identify and develop motivating faculty
Create industry specific syllabus
Develop specialized courses on soft skills
Establish a rich library

For each of the identified business processes, a detailed requirements elicitation exercise was carried out from stakeholders. In this approach, a complete connect and trace is maintained right from system factors, KTA, stakeholder needs, objectives, processes to final business and software requirements.

3.6. Case Analysis

The application of the proposed methodology in the context of the above case resulted in significant value to the overall solution design in terms of correctness and completeness of requirements. Following are some specific instances.

- SIF definition included small towns also as a sub system for analysis which has additional stake holders like the local bodies. The depiction of SIF in the form of CID led to identification of influences from the local bodies, competition on the recruitment system.
- Through SNAC analysis, Parents were identified as a key stakeholder whose attitude towards sending their wards to bigger cities for employment has emerged as constraint which was overlooked previously. This led to creation of new objectives and subsequently modified HR processes for realization.
- The stakeholder analysis along the need dimension leads to identification of constraints which can come in way of realization e.g. TCS need to include industry specific vocational courses in curriculum has multiple constraints: from faculty in terms of willingness to teach these additional courses; from industry bodies such as AICTE for approvals. Ignoring these constraints would mean sub optimal solution.
- Identification of gaps in process capability in terms of sensitive HR processes to address parent's concerns, establishment of network with local bodies to create a contributive environment for the recruitment process.
- Further definition of requirements for the HR processes included: arranging transport for the recruited students from the town to the TCS location, receiving of students at the railway station by HR executives and assistance in arranging for accommodation etc.

4. Conclusion

The paper outlines an approach and demonstrates through a case a methodology for facilitating holistic comprehension of a system by introducing two key models, namely, qualitative cybernetic model and a stakeholder framework. Further, it provides templates and rules to analyze the context information and make significant derivations: key thrust areas (otherwise known as critical success factors) and business objectives aligned to these KTAs. In a structured manner, these objectives are connected and traced to the business processes and requirements for realization. Further, this approach may also be used to chart out a roadmap for developing a software solution for various projects. The differentiators of this context understanding approach are

- Multiple dimensions of a complex system are comprehended and captured on a single platform
- CID™ helps to model the situation holistically in a short span of time.
- Stakeholder framework ensures completeness to the solution design through recognition and capturing of needs from multiple stakeholders who impact or are impacted by the solution.
- Inherent validation and traceability between the two systemic models – stakeholder analysis and cybernetics model
- Identification of potential gaps in processes and requirements early on by integrating the key influences from the environment

The Methodology developed so far has been piloted with encouraging results. Given business systems are complex and most of the models are of a qualitative nature, future work on this is to make it scalable, objective and process driven. One of the works involves creation of tools for wider usage and application in the organization.

Acknowledgements

Authors would like to acknowledge the opportunity given by Ms Vijaya Deepti , Head IISU1 who gave us the opportunity to develop the Methodology and pilot it. We would also like to thank her team Mr Sivakumar Vs, Mr Sampathkumar S, Mr K Ram and Ms Lavanyanagarajan who worked with us closely in creation and deployment of this Methodology.

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