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Abstract

This thesis provides a contemporary review of several topics related to information technology project prioritization, which will help managers create their own custom methodology. Traditional prioritization tools such as weighted average scoring models are used for simultaneous comparison of a number of proposed projects on multiple dimensions, to facilitate alignment with organization goals. These methods are used for the analysis of information related to the weight preferences over criteria used. If used correctly with this procedure, it is possible to bring forward an authentic figure of merit, which is used as the project's strategic potential. This allows the projects to be ranked and the highest-ranking projects to be considered for selection. Visual tools can then be used for selection of optimum project portfolio. The literature dedicates less time on tools beyond the selection of projects. This study aims to bridge this gap by proposing a final phase of project prioritization as Project Portfolio Management.

Acknowledgments

Masters in Interdisciplinary Studies is a challenging program because students are admitted on the basis of an original research proposal and are given the ability to select independent course work tailored to their unique research objectives, offered by various departments within the university. Consequently, students face various challenges. I am indebted to my supervisory committee for supporting me through out the course of my studies. My committee consisting of Prof. Walter Whiteley, Prof. Wade Cook and Prof. Gary Spraakman and I have been very active, I am grateful to receive outstanding feedback and positive evaluations. I am also thankful to all Professors who have allowed me to take their courses. Finally, I would like to thank my family, friends and Allah almighty for making this all happen.

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Problem Definition

The objective of this work is to provide a contemporary review of several topics related to information technology project prioritization which will help managers create their own custom methodology (tools and process) to manage this complex system. This work aims to link academia with the business world with the help of a through literature review, and constructs from various disciplines to 1) disintegrate the problem, and 2) systematically analyze it using the author's own insights gained during his work experience and his enrolment in the interdisciplinary studies program.

Traditional prioritization tools such as weighted average scoring model is used for simultaneous comparison of a number of projects on multiple dimensions, to facilitate alignment with organization goals. This method is used for the analysis of information related to the weight preferences over criteria used. If used correctly with this procedure, it is possible to bring forward an authentic figure of merit, which is used as the project strategic potential. This project value score allows the projects to be ranked and present the highest-ranking projects to decision makers for selection. However, it is not possible to identify optimum project portfolio with scoring model alone as there are many other considerations that need to be taken into account, therefore we evaluate the use of visual tools in combination with scoring models to deal with this complex multi criteria decision making problem.

The literature dedicates less time beyond the selection of projects. Therefore, we propose breaking down prioritization problem into a cycle of three stages namely (1) ranking approved projects, (2) selecting the right projects and (3) evaluating project performance, and

provide insights into how to make this possible using Project Portfolio Management (PPM) framework and viewing this problem via inside and outside view. Looking at the problem in this way will result in more through evaluation of projects under consideration and result in identifying optimum portfolios.

The PPM framework is expected to help the decision makers with prioritization of the projects. It is considered a dynamic decision- making process, represented by a learning loop. The feedback and learning part from each completed project is designed to bring together any insights gained involving a given set of past projects that can be usefully applied to future projects. Then pre and post analysis is carried on so that the actual performance of a project can be compared with initial predictions. To this end, the success of the methodology lies in the reliability of proposed project benefits after forecasting and estimates are brought forward that are usually subjective in nature and often times based on plain guesswork and bad intuition. Therefore, prioritization criteria should be measureable and observable, and should provide a good performance measure of the direction of the entire effort, towards ensuring that this process is not bereft of accountability.

Due to non-availability of real data a general approach has been suited for this study where the research approach uses Multi Criteria Decision Making Theory. The ethnographic design is applied for the research method and the constructivist assumptions are involved in the knowledge assertions where applicable.

Chapter 1: Project Portfolio Management (PPM)

The introduction of the project-based organization has been regarded as one of the recent trends in strategy management[1]. If the strategy is to be changed into reality, packages of work known as projects are formed. Modern organizations separate projects from other operations and characterize projects as a value creation activity. A project consists of a specific mission and is to be completed within a certain time frame, under specific constraints, using resources and managing external constraints[2]. Alignment of strategic organizational goals with projects undertaken is considered the convergent or top to bottom approach. Wherein the higher management gradually decipher the organizational strategy and associated business objectives, they go on to perceive the operational aspects required to achieve the same by reducing the gap between management and processes. Therefore, a multi-project environment exists when several projects are on-going simultaneously, and this is carried out through Project Portfolio Management[3]. According to this management process, organization must not manage the projects on an individual basis and but rather should observe them as unified assets or components of a single large portfolio. The objectives are multiple, but at the same time they are shared. The primary objective of project management is to develop a realistic plan, establish supporting tasks and identify the critical resources, which would help achieve the objectives. However, PPM is also very much focused upon managing the right projects along with questions like what, when and why. It links the strategic goals with on-going operations as illustrated in the Figure 1[4].

[1]Zika-Viktorsson, Annika, Per Sundström, and Mats Engwall. 2006. Project overload: An exploratory study of work and management in multi-
[2]PMI. 2008. Project Management Body of Knowledge. Project Management Institute. Fourth Edition.
[3] Schwalbe, Kathy. 2010. Information Technology Project Management. Cengage. 6 edition: 18
[4] Ibid

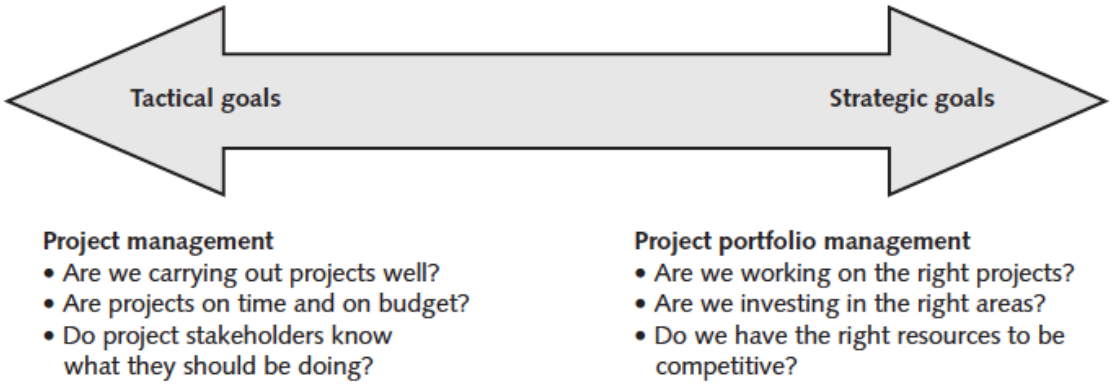

Figure 1 Strategic Goals vs. Tactical Goals (Schwalbe, 2010)[4]

1.1 What is PPM

In this study, the definition presented by (Cooper et al, 2001) and (Gutiérrez, 2012) will be used as it presents a similar idea as stated above. It is believed that project portfolio management is a dynamic decision making process where a constant revision of the active development of projects takes place. The evaluation, ranking and selection of new projects are carried out in this process. Decisions regarding reprioritization, and killing or acceleration of the existing projects are made. The resources are allocated and reallocated accordingly[5] [6].

Change management has long been present within organizations and now project portfolio management has become an emerging aspect within this category. The set of identifiable and specific processes like allowancing, strategic decision making and product development are referred to as dynamic capabilities (Eisenhardt et al, 2000)[7]. It has been stated by (Zahra et al, 2002) that dynamic capabilities are those which have the ability to meet customer requirements and manage competitor strategies through reconfiguration and

[5] Cooper, Robert Gravlin, Scott J Edgett, and Elko J Kleinschmidt. 2001. Portfolio management for new products. 2nd Edition. Perseus Publishing.
[6] Gutiérrez, Ernesto. 2012. Evaluation and selection of ideas and projects in product development. Stockholm: Department of Machine Design KTH, Royal Institute of Technology.
[7] Eisenhardt, Kathleen M, and Jeffrey A Martin. 2000. Dynamic capabilities: what are they?. Strategic management journal 21, no. 10-11: 1105-1121.

deployment of resources. They are observed to be essentially change-oriented capabilities[8]. Well-known Management and Business journals have stated that Strategy and PPM are different concepts that have great importance within the project management research subject[9]. From consulting and academic journals, a vast amount of information has been gathered regarding the project portfolio management discipline[10] [11].

The best practice for PPM has not been presented as all organizations have separate requirements and objectives. A single model for the allocation of resources has also not been presented. The most effective and efficient project portfolio can be maintained through the use of customized tools, methodologies and processes. It is due to this reason that PPM frameworks and process derivatives are present. Hence, it is clear that all organizations and their managers have their own logical reasons for decision-making and management of the project portfolios. Therefore, it is wise to understand the scope of concept of PPM from different studies, as presented in the Figure 2 below taken from recent study by (Young et al, 2013)[12].

[8] Zahra, Shaker A, and Gerard George. 2002. The net-enabled business innovation cycle and the evolution of dynamic capabilities. Information Systems Research 13, no. 2: 147-150.
[9] Kwak, Young Hoon, and Frank T Anbari. 2009. Analyzing project management research: Perspectives from top management journals. International Journal of Project Management 27, no. 5: 435-446.
[10] Kendall, Gerald I, and Steven C Rollins. 2003. Advanced project portfolio management and the PMO: multiplying ROI at warp speed. J. Ross Publishing, April 15.
[11] Wideman, R Max. 2004. A Management Framework: For Project, Program and Portfolio Integration. Trafford Publishing.
[12] Young, Michael, and Kieran Conboy. 2013. Contemporary project portfolio management: Reflections on the development of an Australian Competency Standard for Project Portfolio Management. International Journal of Project Management 31, no. 8: 1089-1100.

Article	Concept							
	Project identification, categorisation and prioritisation	Project opportunity assessment, selection and portfolio balancing	Portfolio performance management and review	Portfolio governance	Portfolio resource management	Portfolio communication and change management	Portfolio risk management	Portfolio leadership
PMI Portfolio Management Standard (Project Management Institute, 2008a, 2008b)	✔	✔	✔	✔			✔	
OGC Portfolio Management Guide (OGC, 2011)	✔	✔	✔	✔	✔	✔	✔	✔
OGC P3M3 PPM Maturity Model (OGC, 2007)			✔	✔	✔	✔	✔	
PM Solutions PPM Maturity Model (J.K. Crawford, 2007; L. Crawford, 2007)	✔	✔	✔	✔	✔	✔		
Parviz, and Levin (2006)	✔	✔	✔	✔		✔		
Association of Project Managers (2006)				✔				
Krebs (2009)	✔	✔			✔			
International Competency Baseline v3 (IPMA, 2008)	✔							
Artto and Dietrich (2004)	✔	✔	✔	✔		✔		
Archer and Ghasemzadeh (1999)	✔	✔	✔					
Blichfeldt and Eskerod (2005)	✔						✔	
Blomquist and Muller (2006)	✔	✔				✔		
Bouraad (2008)				✔				
Cooper et al. (2001)	✔	✔	✔		✔		✔	
Engwall and Jerbrandt (2002)					✔			
Iamratanakul and Milosevic (2007)	✔	✔	✔					
Kendall and Rollins (2003)	✔	✔	✔		✔			
Killen et al.(2008)		✔						
Levine (2005)	✔	✔	✔		✔			
Patanakul and Milosevic (2009)			✔		✔			
Petit and Hobbs (2010)							✔	
Holland and Fathi (2007)							✔	
Meskendahl (2010)		✔						

Figure 2 PPM Functions (Young et al, 2013)[12]

1.2 PPM Process

In the same study by (Young et al, 2013), PPM concepts are explained in Figure 3. These findings are based on a survey, which was industry wide so that concepts are broken down into actionable process elements and standard terminology can be established.

Portfolio manager standard—competency elements.

Unit of competency	Element	Example performance criteria
1. Identification, strategic alignment and prioritisation of projects and programs	1.1 Identification	A regular census is undertaken to identify and capture all ideas, proposed, planned, active or inactive projects and programs in the organisation, the project sponsor and project approval status, to ensure that the project portfolio is complete and correct on an ongoing basis.
	1.2 Strategic alignment	Projects and programs are assessed to determine the degree of alignment with, and contribution to one or more strategic objective.
	1.3 Prioritisation	Organisational prioritisation methods are identified, documented and reviewed to reflect changing organisational priorities.
2. Project opportunity assessment, selection and portfolio balancing	2.1 Screening	Mandatory projects and programs are identified and added to the project portfolio, where appropriate.
	2.2 Investment appraisal	Related projects are grouped for management as a program to ensure that relevant efficiencies are captured.
	2.3 Selection	A project selection model is used to select projects and programs that comprise the portfolio.
	2.4 Approval	Approved projects and programs are provided with identified funding and resources.
3. Portfolio performance management and review	3.1 Program and project delivery oversight	Projects and programs not achieving planned performance are flagged for review and further investigation.
	3.2 Portfolio continuous improvement	Lessons learned are fed into the project selection, prioritisation and portfolio balancing processes.
	3.3 Benefits management and realisation	The portfolio is actively managed to maximise achievement of organisational benefits.
4. Portfolio governance	4.1 Standards, models and approach	Decisions made at authorisation points are recorded and communicated
	4.2 Portfolio charter	A portfolio charter is prepared and regularly reviewed, which clearly establishes portfolio governance and management roles, authorities, approval limits, responsibilities and the scope of portfolio control
5. Portfolio resource management	5.1 Portfolio resource assessment	The resource capacity of the organisation is regularly reviewed and trends identified and assessed
	5.2 Skills and experience assessment	Strategies are implemented to resolve human resource deficiencies and imbalances.
	5.3 Project and program resource assignment	Resource gaps and conflicts are identified and investigated, and appropriate action is taken to resolve the identified resource constraints, in alignment with organisational strategic priorities.
	5.4 Coordination and prioritisation of resources	Resources are reallocated from projects/programs cancelled or put on hold
6. Portfolio communication management	6.1 Portfolio metrics, measurement and reporting	Portfolio data collection processes and systems are integrated into organisational processes and systems
	6.2 Stakeholder engagement and management	Internal and external stakeholders needs are considered in the ideal portfolio mix
	6.3 Communication of portfolio review outcomes	Projects selected for inclusion in and rejection from the portfolio are communicated along with the rationale for the decision
7. Portfolio risk management	7.1 Identification of portfolio risks	Standards and procedures for portfolio risk management are established and continuously reviewed
	7.2 Analysis of portfolio risks	Executive management determine the level of acceptable portfolio risk
	7.3 Monitor and control portfolio risks	Portfolio risks are actively managed to minimise organisational impact
8. Portfolio leadership	8.1 Make strategic decisions	Project/program sponsors are briefed and supported throughout the project/program lifecycles
	8.2 Lead the portfolio team	A portfolio vision is established and clearly communicated to stakeholders

Figure 3 PPM Standard Terminologies (Young et al, 2013)[12]

The practice of PPM is carried out through set processes, which collect and organize into the central database, the information regarding ongoing, proposed and completed projects. These data includes the project name, objectives, resources and timelines etc. Management is able to obtain a bird's eye view of the project through this process. Also, it allows them to extract the inefficiencies present in the project portfolio, such as redundancy. The key success for a business environment is to achieve the optimal balance between the risk and reward

present within the diversified set of projects [13]. Even though individual projects are considered risky for the organization, they may bring about certain opportunities as well. Project performance is monitored and the portfolio is periodically restructured when the PPM process is conducted. Projects are monitored and the ones with cost overruns, changing needs or benefit erosion are removed. The proceeds or resources extracted are used for the new or existing successful projects. When data are efficient and relevant, good decisions are observed. PPM encourages standardized data, which are consistent throughout the organization. Management can then analyze and use this data to make informed and efficient decisions. Analytics that are involved in applying mathematical logic to data before carrying out the decisions, are provided with thorough information. They can easily and quickly access this information, review it and compare it across several other projects. Project prioritization decisions are being supported, the evaluation criteria and key objectives are aligned with chosen projects and effective management of the financial and business choices of the organization are carried out. According to (Archer et al, 1999), PPM must be carried out in three phases, which are the following. The first phase is (A) Strategic considerations phase, followed by (B) portfolio selection phase and lastly the (C) post selection phase[14]. A similar model was brought forward by (Bible et al, 2011). This process is divided into three PPM areas namely (1) Strategic Planning, Identify, (2) Evaluate & Select Project Portfolio and (3) Monitor, Evaluate & Control. Each PPM area is further sub divided into respective phases as columns where each column lists the activities required to produce an output that acts as an input for the next phase, illustrated in Figure 4[15].

[13] Young, Michael, and Kieran Conboy. 2013. Contemporary project portfolio management: Reflections on the development of an Australian Competency Standard for Project Portfolio Management. International Journal of Project Management 31, no. 8: 1089-1100.
[14] Archer, Norm P, and Fereidoun Ghasemzadeh. 1999. An integrated framework for project portfolio selection. International Journal of Project Management 17, no. 4: 207-216.
[15] Bible, Michael J, Susan Bivins, and Susan S Bivins. 2011. Mastering project portfolio management: a systems approach to achieving strategic objectives. J. Ross Publishing.

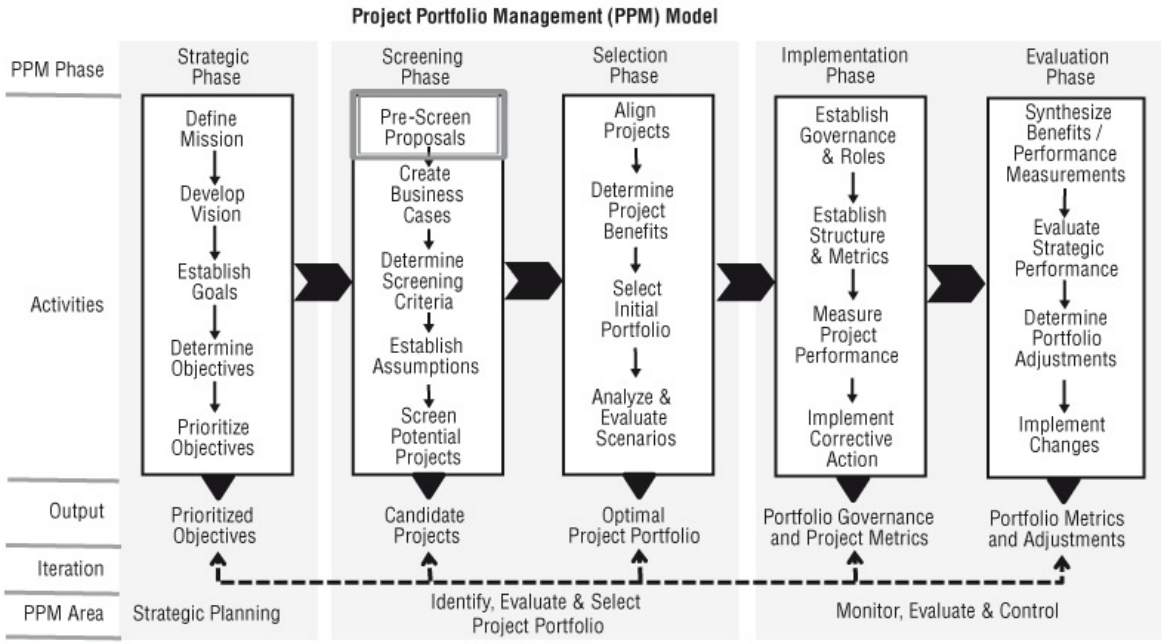

Figure 4 Standard Project Portfolio Management Model (Bible et al, 2011)[15]

PPM is a dynamic decision making process. (Dooley et al, 2005) referred to it as learning loop process. They proposed the feedback and learning part from each completed project within the portfolio to measure how effectively the projects have contributed to their objectives i.e. organization goals, as this could help project-based organizations when initiating future projects. Moreover, it was pointed out that during project selection, managers wrongly argue that due to unique characteristics of each project that are different from one another, hence rendering historic information from projects previously carried out redundant (Dooley et al., 2005)[16].

(Stewart, 2008) discussed the management framework of Information Technology project life cycles. This framework, which is shown in Figure 5, is comprised of three components and each component expresses a phase of the cycle: (1) Selecting IT project; (2) Strategic implementation of IT; (3) IT performance evaluation. No stage should be

[16] Dooley, L, G Lupton, and D O'Sullivan. 2005. Multiple project management: a modern competitive necessity. Journal of Manufacturing Technology Management 16, no. 5: 466-482.

considered as separate and independent in this cycle because the obtained information in each stage can be useful for supporting the other stages[17]. The work of (Archer et al., 1999) can be referred for the project portfolio selection process[18,19]. Therefore in light on these references the project prioritization process should not only be conducted in the project selection phase, but continuously during the portfolio cycle.

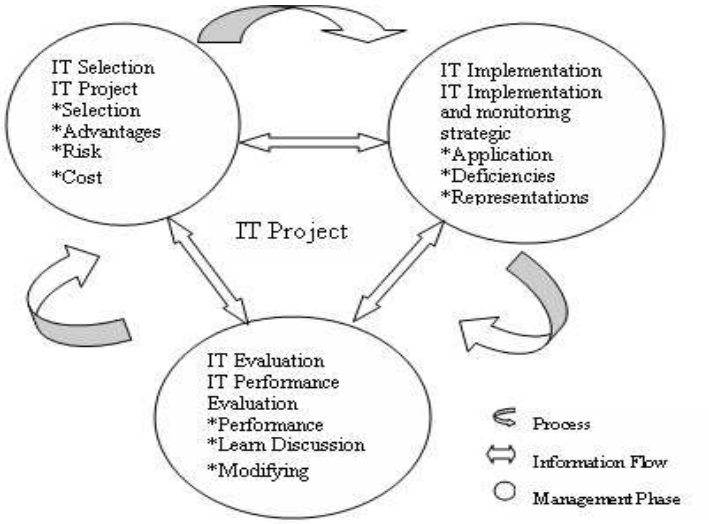

Figure 5 IT Project Life cycle (Stewart, 2008)[17]

1.3 PPM Challenges

Strategic execution is the activity that differentiates the organization from its competitors[20]. (Mark et al, 2007) has noted the importance of a tailored portfolio of projects that would bring strategy to life with greater efficiency, as it is essential to realize, given the nature of business today, that organizations have to work with decreasing resources while customer

[17] Stewart, Rodney A. 2008. A framework for the life cycle management of information Technology projects: Project IT , International Journal of Project Management, 26: 203–212
[18] Frame, J. D. 1994.. Selecting Projects that Will Lead to Success. Reprinted in: Dye, Lowell D, and James S Pennypacker. 1999. Project portfolio management: selecting and prioritizing projects for competitive advantage. Center for Business Practices.
[19] Archer, N.P. and Ghasemzadeh, F. (1999). An Integrated Framework for Project Portfolio Selection.International Journal of Project Management, 17 (4), 207-216.
[20] Michael, E. Porter.1996. What is Strategy. Harvard Business Review: 61-78.

demands are increasing. Therefore the organization needs to carefully decide where to invest[21]. A critical aspect of project portfolio management is the project prioritization decision that is considered a weakest facet, whereby the best set of projects is selected from many competing proposals, when many are technically and financially viable.

Selection of a set of projects from those presented to management is a challenge as organizations aim to maximize the effectiveness of a project portfolio. Hence, the selection of the best composition of projects needs a systematic approach that considers the strategic objectives and constraints (Pennypacker et al, 2002)[22]. According to (Markowitz et al, 2000) another portfolio challenge is balancing return and risk using an efficient frontier where returns from assets in a portfolio are maximized for any level of acceptable risk or minimum risk for an expected level of return[23]. While significant research has focused on the risk side of portfolio management and selection, this is considered to be an open problem, and there is a call for developing innovative methods. As one must understand the important distinction between financial portfolios and project portfolios, theories on how to combine these disciplines more seamlessly have not yet emerged (Benko et al, 2003)[24]. Similarly, (Casault et al, 2013) argue direct application of financial risk theory is problematic[25]. In fact, when it comes to projects, the returns are multi-dimensional in nature. This way the decision makers are able to provide an accurate representation of strategic business value by reflecting the entire project in terms of tangible and intangible benefits accruable in the future (Urli et al, 2010)[26]. Project returns

[21] Morgan, Mark, William A Malek, and Raymond E Levitt. 2008. Executing your strategy. Harvard Business School Press, January 7.
[22] Pennypacker, James S, and Lowell D Dye. 2002. Project portfolio management and managing multiple projects:two sides of the same coin. Managing multiple projects: 1-10.
[23] Markowitz, Harry M, G Peter Todd, and William F Sharpe. 2000. Mean-variance analysis in portfolio choice and capital markets. John Wiley & Sons.
[24] Benko, Cathleen, and Franklin Warren McFarlan. 2003. Connecting the dots: Aligning projects with objectives in unpredictable times. Harvard Business Press.
[25] Casault, Sebastien, Aard J Groen, and Jonathan D Linton. 2013. Selection of a portfolio of R&D projects. Handbook on the Theory and Practice of Program Evaluation: 89.
[26] Urli, Bruno, and François Terrien. 2010. Project portfolio selection model, a realistic approach." International Transactions in Operational Research 17.6: 809-826.

are uncertain and can be difficult to estimate, due to this, effectiveness of project portfolio is only reflected over a period of time (Cooper et al, 2001)[27]. In many cases the stakes are high because selecting projects is a significant resource allocation decision that can materially affect the operational efficiency of a firm[28]. Moreover in the competitive landscape and changing business conditions organization's survivability may depends on it[29].

Project Portfolio Selection is a natural extension of change management. It is a complex process regardless of organization size, especially due to long payback periods, changing business conditions and the information at hand consisting merely of forecasts and estimates leaving new initiatives with high level of uncertainty. Some other challenges are typically a shortage of human resources, lack of time and budgetary constraints, conflicting demands from stakeholders, projects with conflicting requirements and biases and errors in judgment resulting in inaccurate estimates when selecting projects and short term plans vs long term plans conflict[30]. Due to the multiple criteria involved and the lack of the right metrics for valuing projects; inability to assess and value risk; unknowingly take on high-risk projects; make project choices based on political considerations not in the best interest of the firm and not undertaking an objective approach when dealing with the conflicting expectations of the various stakeholders involved[31].

There are 3 categories of issues according to (Rintala et al, 2004). First, resource allocation can be an issue in an environment that consists of several projects. There can exist a

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[27] Cooper, Robert Gravlin, Scott J Edgett, and Elko J Kleinschmidt. Portfolio management for new products. 2001. Basic Books, 2nd Edition. United States: Perseus Publishing.
[28] Chen, Chen-Tung, and Hui-Ling Cheng. 2009. A comprehensive model for selecting information system project under fuzzy environment. International Journal of Project Management 27, no. 4: 389-399.
[29] Santhanam, Radhika, and Jerzy Kyparisis. 1995. A multiple criteria decision model for information system project selection. Computers & Operations Research 22, no. 8: 807-818.
[30] Sowlati, Taraneh, Joseph C Paradi, and C Suld. 2005. Information systems project prioritization using data envelopment analysis. Mathematical and Computer Modelling 41, no. 11: 1279-1298.
[31] Engwall, Mats, and Anna Jerbrant. 2003. The resource allocation syndrome: the prime challenge of multi-project management?. International journal of project management 21, no. 6: 403-409.

lack of transparency between the projects or some workers may be overloaded while others have no work at all. Second, the strategic context of project composition may be an issue. The strategy and projects may not be aligned or the balance may not be optimally against the several objectives within the portfolio. Third, the activities may be influenced by an overload of information or the lack of information[32]. Many other issues are present such as the lack of coordination present among the projects, the objectives of the projects may conflict, the resources may face unexpected bottlenecks, the project delivery may be late, the business leaders may lack commitment, the cross functional working may not be effective, the final project benefits may be lacking and the organization may resist any kind of change [33].

(Cooper et al, 2000) states the balancing of resources, carrying out decisions without concrete information and the presence of minor projects within the portfolio are the main issues present. Usually, organizations are interested in quick wins for which they include small projects within the portfolio and have only a few successes[34]. (Elonen et al, 2003) states that the managerial issues present within project portfolios is the weak link between project selection and business strategy, the reluctance to terminate projects and the poor quality of the projects [35]. Also, as per (Staw et al, 1987) lack of focus, scarce resources, inclusion of easy and short term projects, lack of information quality and power based decision making are added issues[36]. The generic issues present within the PPM process have been presented by (Kendall et al, 2003) as follows. Firstly, there is a presence of too many active projects, no value is added by the projects, the strategic goals and projects are not linked and there is no balance present in the

[32] Rintala, K, Poskela, J, Artto, K.A, and Korpi-Filppula, M. 2004. Information system development for project portfolio management. Management of technology, Internet economy, opportunities and challenges for developed and developing regions of the world In: Hosni, Y.N. and Khalil, T.M. (eds.): 266-267.

[33] Payne, John H. 1995. Management of multiple simultaneous projects: a state-of-the-art review. International journal of project management. 13, no. 3: 163-168.

[34] Cooper, Robert G, Scott J Edgett, and Elko J Kleinschmidt. 2000. New problems, new solutions: making portfolio management more effective. Research-Technology Management 43, no. 2: 18-33.

[35] Elonen, Suvi, and Karlos A Artto. 2003. Problems in managing internal development projects in multi-project environments. International Journal of Project Management 21, no. 6: 395-402.

[36] Staw, B.M. and Ross, J.1987. Knowing when to pull the plug. Harvard Business Review, Vol. 65. 2, 68-74.

portfolio and that there is no right way to balance[37]. (Kendall et al, 2003)[38] define an unbalanced portfolio as follows;

1. Too much on the supply side, not enough on the market side
2. Too much development, not enough research
3. Too much short term, not enough long term
4. Not reflective of the organization's most important assets
5. Not reflective of the organization's strategic resource value
6. Not reflective of major product revenue opportunities risks, etc.

The strategic bucket method of PPM was developed by (Cooper et al., 2001) which allows for balancing of organization goals. This method is comprised of three steps: first, strategic buckets are defined such as "radical products", "incremental product improvements", and "maintenance products" and "product lines" etc. Thus, strategic buckets also referred to as packets of resources are created. This is advantageous because spending at year-end will accurately reflect the strategic priorities of the organization. Second, resources are allocated between these buckets. And lastly, all projects are assigned to the appropriate bucket and the project portfolio of each bucket is optimized by choosing the most suitable projects until the resources of the strategic bucket run out. Despite its attractiveness, this method forces many complicated decisions e.g. selection of appropriate buckets, allocate resources over these buckets, and finally optimize projects portfolios within those buckets[39].

A further complexity of the PPM problem as stated by (Loch and Kavadias, 2002) is that the cost of a individual project can depend on decisions made about other projects when sharing resources via procurement discount[40]. (Chun, 1994) made the point that the timing of tasks within projects is crucial and that these need to be considered when making PPM decision. For

[37] Kendall, Gerald I, and Steven C Rollins. 2003. Advanced project portfolio management and the PMO: multiplying ROI at warp speed. J. Ross Publishing, April 15.
[38] Ibid.
[39] Cooper, R.G., S.J. Edgett, E.J. Kleinschmidt. 2001. Portfolio Management for New Products, 2 nd Edition. United States: Perseus Publishing.
[40] Loch, C.H., S. Kavadias. 2002. Dynamic portfolio Selection of NPD programs using marginal returns. Management Science,. 48 (10), 1227-1241.

example, if two projects have tasks that can be sequenced effectively, this should be recognized as an advantage when choosing which projects to pursue[41]. To address these shortcomings (Groenveld, 2007) recommended a mapping methodology that relates technologies to the potential products and to final markets. Using a precedence network approach, the method incorporates the interdependencies between projects and their potential economic benefit. The product-technology roadmaps are diagrammed on a horizontal time axis. This technique shows the links between projects and the strategy of the company; but it does not address the balance of the portfolio or maximize monetary return[42,43].

In another study some firms admitted to having too many trivial projects in their product pipeline[44]. Problems discussed above, evaluated by a survey conducted by (Buys et al. 2010) summarizes issues in PPM as follow in Figure 6[45].

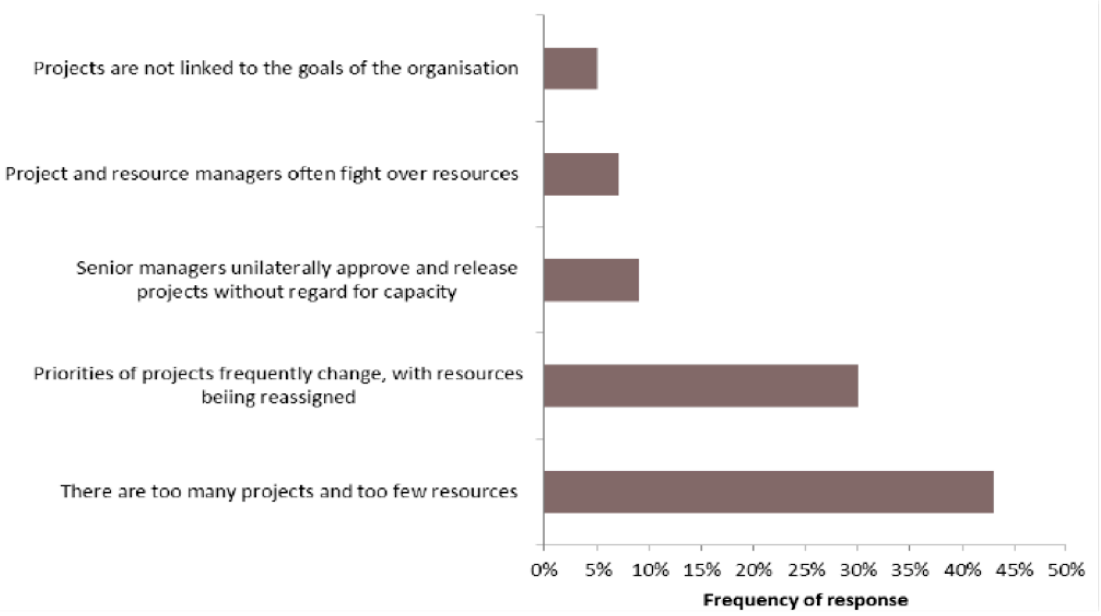

Figure 6 Challenges in PPM (Buys et al, 2010)[45]

[41] Chun, Y.H. 1994. Sequential decision under uncertainty in the R&D project selection problem. IEEE Transactions on Engineering Management, 40 (4), 404-413.
[42] Groenveld, Pieter. 2007. Roadmapping integrates business and technology. Research-Technology Management 50, no. 6: 49-58.
[43] Dickinson, Michael W, Anna C Thornton, and Stephen Graves. 2001. Technology portfolio management: optimizing interdependent projects over multiple time periods. IEEE Transactions on engineering management 48, no. 4: 518-527.
[44] Cooper, Robert G, Scott J Edgett, and Elko J Kleinschmidt. 1997. Portfolio management in new product development: Lessons from the leaders—I. Research-Technology Management 40, no. 5: 16-28.
[45] Buys, Andre J, and MJ Stander. 2010. Linking projects to business strategy through project portfolio management. South African Journal of Industrial Engineering 21, no. 1: 59-68.

(Engwall et al, 2003) believes that resource allocation across several projects can prove to be a challenging task due to what he calls the "resource allocation syndrome" that is regarded as the key problem of multi-project organizations. Such a syndrome states that allocation and reallocation of scarce resources is a complex task as it affects the portfolio along with the interdependent projects within the portfolio. Such an activity establishes a short-term problem solving environment where reactive behavior is the main focus[46]. This issue was also supported by (Mintzberg, 1999 ; Mintzberg, 2007) An intended strategy is what an organization follows as it guides its future activities and acts as a plan. The situations in a dynamic environment need to be managed efficiently, which is why emergent strategies are established, that help assist the intended strategy to bring forward a realized strategy[47,48]. At such a time, the reallocation of resources proves to be a complex task. Psychological and cultural factors at times cause hindrance in the implementation of strategy for instance; the management of a service organization might anchor on to carrying out certain activities, as they are thorough, efficient and comfortable in conducting these activities. With such an attitude, the organization may fail if an unexpected change or crisis is to take place demanding a radical reassessment of the organization objectives and management failing to adapt.

Many believe that the management of projects becomes complex due to PPM. This may be true, as now the projects are not considered as floating islands within the enterprise. Even though PPM is considered to increase the success rate of the organization, many have not completely adopted the concept (Blichfeldt, et al, 2008)[49]. This issue has led to a decline in the popularity of PPM. The investment required for developing and implementing the tools and

[46]Engwall, Mats, and Anna Jerbrant. 2003. The resource allocation syndrome: the prime challenge of multi-project management?. International journal of project management 21, no. 6: 403-409.
[47]Mintzberg, Henry. 2003. The strategy process: concepts, contexts, cases. Pearson education.
[48]Mintzberg, Henry. 2007. Tracking strategies: Toward a general theory. Oxford University Press on Demand.
[49]Blichfeldt, Bodil Stilling, and Pernille Eskerod. 2008. Project portfolio management–There's more to it than what management enacts. International Journal of Project Management 26, no. 4: 357-365.

procedures, the training involved and the organizational environment change, act as the barriers in the PPM system establishment. The issues regarding portfolio management implementation have been defined by (Levine, 2005)[50] as the benefits and ranking value, the portfolio pipeline, the uncertainty impact of the portfolios and projects and the risks and benefits relationship present. These challenges result in choosing the wrong projects with the use of inefficient decision-making processes that fail to create an environment of accountability creating a barrier to establish an effective framework for project portfolio management.

As demonstrated by the broadness of this literature review, the PPM problem has attracted interest from many different researchers. The methodologies used to analyze PPM branched into two distinct paths: qualitative and quantitative approaches[51]. Please refer to (Verbano et al, 2010), who provide an excellent review of PPM tools[52]. The inherent problem with PPM tools and methods is very clearly illustrated by a study conducted by (Wind et al, 1983;Triantaphyllou, 2000). They demonstrated that project recommendations could vary significantly depending on the PPM tool used to make a project selection[5354]. Using a blend of qualitative and quantitative methods makes it difficult to define an ideal portfolio and can promote information overload [55]. Consequently, decision makers frequently select their portfolio using a combination of professional judgment and/or scoring method as discussed later on [56]. Furthermore, existing work on PPM project selection models have focused on special cases, such as modeling resource constraints quantitatively and balancing portfolio

[50] Levine, Harvey A. 2007. Project portfolio management: a practical guide to selecting projects, managing portfolios, and maximizing benefits. John Wiley & Sons, September 1.
[51] Dickinson, Michael W, Anna C Thornton, and Stephen Graves. 2001. Technology portfolio management: optimizing interdependent projects over multiple time periods. IEEE Transactions on engineering management 48, no. 4: 518-527.
[52] Verbano, Chiara, and Anna Nosella. 2010. Addressing R&D investment decisions: a cross analysis of R&D project selection methods. European Journal of Innovation Management 13, no. 3: 355-379.
[53] Wind, Y., V. Mahajan, D.J. Swire. 1983. An empirical comparison of standardized portfolio models. Journal of Marketing, 47, 89-99.
[54]Triantaphyllou, Evangelos. 2000. Multi-criteria decision making methods. Multi-criteria Decision Making Methods: A Comparative Study: 5-21.
[55] Cooper, Robert G, Scott J Edgett, and Elko J Kleinschmidt. 1997. Portfolio management in new product development: Lessons from the leaders—I. Research-Technology Management 40, no. 5: 16-28.
[56] Dickinson, Michael W, Anna C Thornton, and Stephen Graves. 2001. Technology portfolio management: optimizing interdependent projects over multiple time periods. IEEE Transactions on engineering management 48, no. 4: 518-527.

qualitatively[57]. However, both branches remained focused on dealing with prioritization as a separate process and did not link it with post implementation phase to validate new project proposals in light of past comparable project data. In spite of the large amount of literature on this topic, a significant gap exists e.g. the unique feature of the project portfolio application is the presence of two sets of data, namely pre-implementation estimates, and post-implementation "actuals". Evaluating a proposed project against these two data sets of comparable past projects can provide the basis for making project portfolio choices. More to the point it is often the case that pre estimates of project outcomes/benefits tend to be over stated and consist of various tangible and non-tangible factors which are uncertain and can be difficult to estimate. Therefore, project portfolios need to be evaluated by means of quantitative analysis that can translate the "pre" performance estimates into estimated "post" performance values.

1.4 PPM Benefits

The PPM adoption level is correlated to the organization benefits perceived and the issues faced when project management takes place. When an increase in the PPM adoption level is observed, a significant positive impact is realized on portfolio project return. At the same time, there is a significant negative impact on the project related issues reported [58]. An advantage regarding PPM was reported by (Thorp, 1999) as he described that it has the ability to reduce the inter-project competition for resources as well as change the project overlaps to the productive interdependencies. The interdependencies being observed are bottleneck changes, scarce resources competition and outcomes overlap[59].

[57] Ibid
[58] De Reyck, Bert, Yael Grushka-Cockayne, Martin Lockett, et al. 2005. The impact of project portfolio management on information technology projects. International Journal of Project Management 23, no. 7: 524-537
[59] Thorp, J. 1999. The Information Paradox – Realizing the business benefits of IT. Toronto: McGraw-Hill.

Organizations in any industry can benefit from PPM. Several literature studies have stated the same. For instance, the importance of PPM has been presented by (Pennypacker et al, 2009)[60] where it is clearly stated that the potential benefits for the organizations can be immense. Several benefits of PPM were also presented by (Cooper et al, 2000) which include financial benefits like increase in market share and sales. It was also stated that a link between business strategy and project selection is formed, and a competitive position is maintained[61]. According to (Rad et al, 2008), an improvement in the project team's effectiveness takes place, overall project costs are reduced and competitive position is strengthened[62]. There exists a negative impact upon the number of project issues reported, and a positive impact upon project return based on the amount of PPM adopted by the organization (Reyck et al, 2005)[63]. A governance perspective was brought forward by (Filippov et al, 2010) where he described PPM as protecting the organization from harm by removing all inappropriate projects from the project portfolio[64]. (Levine, 2005) sees PPM as more than a bridge, and brought forward the concept of a hub as illustrated in the figure 7 below [65]:

[60]Pennypacker, J, and S Retna. 2009. Project Portfolio management: A view from the management trenches. Hoboken: John Wiley & Sons.
[61] Cooper, Robert G, Scott J Edgett, and Elko J Kleinschmidt. 2000. New problems, new solutions: making portfolio management more effective. Research-Technology Management 43, no. 2: 18-33.
[62] Rad, Parviz. Levin, Ginger. 2008. What is project portfolio management?. AACE International Transactions15287106: TC31-TC34.
[63]De Reyck, Bert, Yael Grushka-Cockayne, Martin Lockett, et al. 2005. The impact of project portfolio management on information technology projects. International Journal of Project Management 23, no. 7: 524-537.
[64] Filippov, Sergey, Herman Mooi, and Roelof van der Weg. 2012. Strategic project portfolio management: An empirical investigation. Journal on Innovation and Sustainability. RISUS ISSN 2179-3565 3, no. 1.
[65] Levine, Harvey A. 2007. Project portfolio management: a practical guide to selecting projects, managing portfolios, and maximizing benefits. John Wiley & Sons.

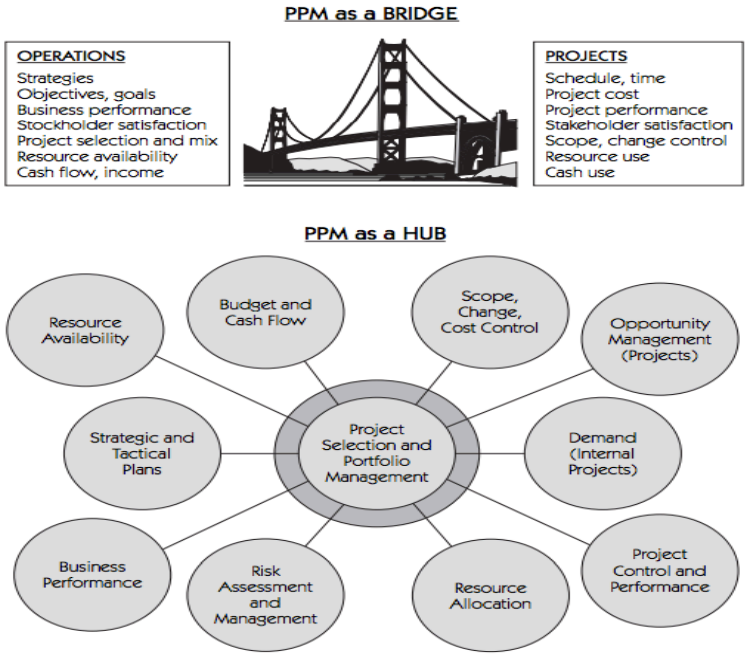

Figure 7 Scope of PPM (Levine, 2007)[65]

(Robert, 2004) and (Harvey, 2005) provides an overview of the benefits of PPM and see it as much deeper than the traditional project management when the strategy execution process is to take place[66,67].

1. There is need and opportunity identification, benefits and value ranking
2. Carrying out the selection of the objective undertaking of the projects
3. Carrying out selection for the deferred and terminated projects
4. Project priorities communication and establishment
5. Cash flow revenue and effect projections
6. Firm projects value and benefits estimations
7. Evaluating whether the benefits are adequate enough to overcome the predicted risks, protecting and enhancing the future of the firm by making sure there exists a balance between the project types, the firm resources which includes people and others should be used appropriately by limiting the number of projects and
8. Benefit realization and product launch

[66] Levine, Harvey A. 2007. Project portfolio management: a practical guide to selecting projects, managing portfolios, and maximizing benefits. John Wiley Sons.
[67] Wideman, R Max. 2004. A Management Framework: For Project, Program and Portfolio Integration. Trafford Publishing.

(Sanwal, 2007; Cooper et al, 2001) presents the following reasons behind the importance of PPM. The financial aspects include the maximization of the returns by including and identifying the right projects, maximization of the technology and R&D productivity, and the achievement of the strategic goals. They observed that the allocation of resources is carried out effectively and appropriately. The business strategy and project selection link is formed where the portfolio is regarded as the expression of the strategy. This allows for reconciling the budgets from top to bottom with bottom-up investments i.e. on going projects across active project portfolio. Resources are limited, which is why not many projects are carried out and focus is maintained. The optimal balance between short and long term projects is maintained along with the high and low risk ones, and market growth and market share ones which are based on the business goals and objectives. The organization communication process is enhanced in a vertical and horizontal manner. The project selection process now becomes objective and all bad projects are avoided. Hence, it can be stated that through PPM, effective resource allocation process is carried out along with alignment of the business and project objectives. Group communication is also enhanced and overall high profitability is attained[68,69].

[68] Cooper, Robert Gravlin, Scott J Edgett, and Elko J Kleinschmidt. 2001. Portfolio management for new products. Basic Books.
[69] Sanwal, Anand. 2007. Optimizing corporate portfolio management: aligning investment proposals with organizational strategy. John Wiley and Sons, July 20.

Chapter 2 : Projects vs. Programs vs. Portfolios

The project management office (PMO) also referred to as the program office is a well-known organizational structure used for the management of projects. It is an entity which helps project managers, and other management levels and teams with strategic aspects and functional entities within the organization at large. PMOs are now able to efficiently implement the project management tools, techniques, methodologies, practices and principles[70]. It is common knowledge that without project management, the strategic transformation process cannot be carried out by management. A unique set of coordinated activities that have definite starting and ending points, which are managed by an individual or team within the organization to achieve a certain objective, is referred to as project management[71]. Projects are different from programs, as programs may not have a fixed time limit, a clearly defined objective or a single objective[72]. Strategic goals of modern organizations are attained through programs. Effective program management can help achieve strategic objectives through implementation of related projects[73].

[70] Ward, J LeRoy. 2000. Project management terms: a working glossary. ESI Intl.
[71] Office of Government Commerce. 2009. Managing successful projects with PRINCE2. The Stationery Office.
[72] Pellegrinelli, Sergio. 1997. Programme management: organising project-based change. International Journal of Project Management 15, no. 3: 141-149.
[73] PMI. 2013. The Standard for Program Management. Project Management Institute. Third Edition.

2.1 Portfolio Management

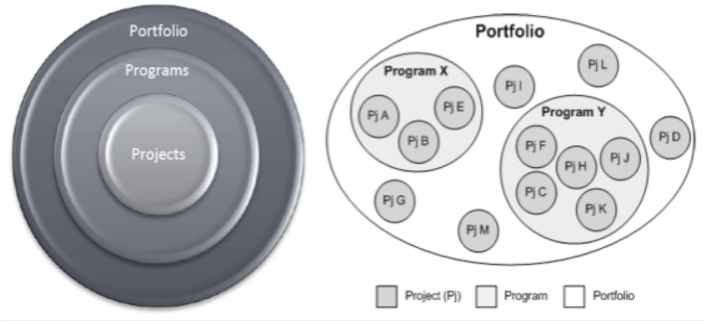

Figure 8 Projects Programs and Portfolios (Rajegopal et al, 2007)[74]

The various projects and programs are gathered into a portfolio with current components and future initiatives. The programs and projects may be related or may not be related. The Figure 8 shows the project, program and portfolio relationships present[74]. Project Portfolio Management has been defined by (Mark et al, 2007) as a path that executes strategy, which is separate from the one that goes on during project portfolio management as it is expected to lie between Project management and Portfolio management[75]. The strategy must be precise through objective analysis in order to be efficiently budgeted and implemented. The central idea is to establish an appropriate link between the goals of the organization and the activities conducted. The strategic level within the organization consists of Portfolio Management and this is where it is operated. This process highlights measureable ways to accomplish organization objectives. Decision makers carry out the reprioritization of strategic objectives when the focus of the organization changes and the strategic realignment is expected to take place. For such cases, the management of the overall company strategy is regarded as Portfolio Management.

[74]Rajegopal, S., McGuin, P. and Waller, J. 2007. Project portfolio management: Leading the corporate vision, Palgrave Macmillan, Hampshire.
[75] Mark Morgan: Raymond E. Levitt. 2007. William Malek. Executing your strategy. How to break it down & get in done. Harvard business school press.

A portfolio is the total investment of an organization or its segment where the changes are used to achieve strategic objectives (Levine, 2007)[76]. Several other definitions are present but this one has been used for the present thesis. It may also be known as collection of projects where grouping is done to carry out effective management and achieve strategic objectives. The portfolio components are quantifiable and interdependent (PMI, 2008)[77]. The coordinated management of portfolio components is known as portfolio management[78]. A finite life is not present for a portfolio as is the case for programs and projects. The portfolio needs to remain consistent with the objectives of the organization, as well as in balance, which is why it should be regularly and continuously trended whereby changes in form of new projects are added. Various characteristics are present within a portfolio decision process, which includes dynamic opportunities, multiple goals, multiple decision makers, locations, interdependence among projects and programs, and an uncertain and changing information. (Terwiesch et al, 2008) enumerates four basic tasks in portfolio planning. First, identification of the present and future gaps in the portfolio relative to the strategy. Second, the exploration of a new market of technologies and the present strategic position of the organization must be brought into balance. Third, devising a portfolio with the highest potential financial value. Finally, analyzing the level as to how much redefining of the competition can take place[79].

(Schwalbe, 2010) outlook on portfolio management is presented in this paragraph. The listing of existing, planned or proposed portfolio components and their classification into relevant organization groups is referred to as categorization. The author further includes portfolio component's evaluation, selection and prioritization to be carried out after subjecting them to a common set of decision filters and criteria. In order to improve portfolio performance

[76] Levine, Harvey A. 2007. Project portfolio management: a practical guide to selecting projects, managing portfolios, and maximizing benefits. John Wiley & Sons.
[77] PMI. 2008. Project Management Body of Knowledge. Project Management Institute. Fourth Edition.
[78] PMI. 2013. Project Management Institute. The Standard for Program Management Third Edition.
[79]Terwiesch, Christian, and Karl Ulrich. 2008. Managing the opportunity portfolio. Research-Technology Management 51, no. 5: 27-38.

it is important to measure the project portfolio as a whole, and not only the projects within. Portfolio components may fall into a common group with similar goals, and therefore should be measured relatively in the same way irrespective of their origin within the organization. Based on qualitative and quantitative information, which is gathered and summarized for each of the components, the organization is able to balance the investment based upon their relative alignment with strategic objectives. The group components are responsible for achieving the outcomes, and portfolio management acts as a governing body. Tools and techniques are used by the organization to select, prioritize, monitor and govern the component contributions and their alignment with the objectives[80]. If the process is not evaluated correctly, the portfolio components would be poor and the workload of the organization would increase[81].

According to (Levine, 2007) the following aspects are present within portfolio management. They are achieving goals and defining objectives, analyzing, accommodating and establishing trade-offs, risk diversification, minimization, elimination, identification and finally portfolio performance monitoring[82]. (PMI, 2013) gives some more insight i.e. components of a portfolio contain common features such as the following. At first it is the organization's investment planning or application that is represented. Secondly, the strategic objectives and goals of the organization are aligned. Thirdly, it is possible to carry out the prioritization, ranking and measuring since they are quantifiable. Lastly, several distinguishing features are present which allow the organization to carry out effective management through grouping[83].

[80] PMI. 2013. Project Management Institute. The Standard for Portfolio Management Third Edition.
[81] Schwalbe, Kathy. 2010. Information Technology Project Management. Cengage
[82] Levine, Harvey A. 2007. Project portfolio management: a practical guide to selecting projects, managing portfolios, and maximizing benefits. John Wiley & Sons.
[83] PMI. 2013. Project Management Institute. The Standard for Portfolio Management Third Edition.

2.2 Information Technology Portfolio Management

Organizations are now considering the importance of capital investment in information technology (IT). A major portion of the capital spending is carried out over this. The organizational competencies are very much dependent upon the wise investment regarding IT and management strategies. IT is no longer considered a strategic asset but is regarded as a commodity (Carr, 2003)[84]. High performance has been observed within those organizations that have an efficient alignment between their IT investments and business strategy. This has been demonstrated through empirical evidence (Chan et al, 1997)[85]. Hence, many organizations now believe that success can be attained through the strategic use of IT (Weill et al, 1998)[86]. Firms are subjected to major challenges due to the strategic misalignment of IT with the business objectives, which are constantly changing due to the globalized and competitive environment[87]. Understanding customers along with managing their technical issues can maintain the competitive advantage of the organization. Market and technological uncertainty is usually observed by such organizations. The delivery and provision of services and equipment is carried out through the extensive use of technology.

During the implementation of the business strategy, there are 4 essential services provided by IT to the organization. These are information availability, automation of the business processes, customer connections and productivity tools or aids provisions (Sharpe et al, 2008)[88]. According to (Huang, 2009) the value added to the organization by an IT project can be determined by the following key words: better, cheaper, faster, and do more in prescribed time

[84] Carr, NG. 2003. IT doesn't matter. Harvard Business Review 81, no. 5: 41-49.
[85] Chan, Yolande E, Sid L Huff, Donald W Barclay, and Duncan G Copeland. 1997. Business strategic orientation, information systems strategic orientation, and strategic alignment. Information systems research 8, no. 2: 125-150.
[86] Weill, P. Broadbent, Marianne. 1998. Leveraging the new infrastructure: how market leaders capitalize on information technology. Harvard Business Press.
[87] Nakata, Cheryl, Zhen Zhu, and Maria L Kraimer. 2008. The complex contribution of information technology capability to business performance. Journal of Managerial Issues: 485-506.
[88] Sharpe, Andrew, and Jean-Francois Arsenault. 2008. ICT Investment and Productivity: A Provincial Perspective. Centre for the Study of Living Standards.

period, such as in a quarter, year, or any timeframe specified by the organization. The first three key constructs concentrate on efficiency, quality and effectiveness, while the latter one is aimed towards growth. As per (Huang, 2009) several benefits are achieved through investments in the field of IT such as[89]:

1. Decrease in the operational expenses of the processes;
2. Improving productivity and market share;
3. Improving economic benefits and profitability;
4. Attaining competitive edge;
5. Facilitating strategic programming;
6. Establishing a balance between organizational objectives;
7. Attaining managerial endorsement and information structure;
8. Improving responsiveness and fulfilling the expectations of customers;
9. Enhancing quality.

There are other advantages as well, including speed of operation, consistency and stability in development of data and accessibility to information and its transfer amongst different industries[90]. There is immense use of IT for strategic objectives, which can also boost organizational efficiency by enhancing internal process regulation and efficiency[91].

The central component of IT infrastructures is the Information Systems (IS). The investment carried out for IS is part of essential strategic decisions, and increase the value of the firms' (IT) infrastructure capability. Information Systems is an important tool available to managers for achieving higher levels of efficiency and productivity in business operations, due to the ongoing revolution by assisting the industrialized and emerging markets in their capacity to act as inter-operable systems. Committing resources to the development of the IS and its capabilities can enhance the organizational performance in terms of economics and quality

[89] Huang, Hao-Chen. 2009. Designing a knowledge-based system for strategic planning: A balanced scorecard perspective. Expert Systems with Applications 36, no. 1: 209-218.
[90] Stewart, Rodney A, and Sherif Mohamed. 2003. Evaluating the value IT adds to the process of project information management in construction. Automation in Construction 12, no. 4: 407-417.
[91] Stewart, Rodney A. 2008. A framework for the life cycle management of information technology projects: ProjectIT. International Journal of Project Management 26, no. 2: 203-212.

(Daugherty et al, 2005)[92]. Information systems have revamped the ways of conducting business that provide firms with strategic advantage by providing a foundation to sophisticated new product development, operations, marketing strategies, product strategies and enables creation of new services[93]. E.g. cost reduction and effective business relationship building is possible through investments made in IS. The customers may return to the organization for repurchase if they have been provided with satisfactory service or offerings. Hence, IS has now transitioned from being able to support the organization to help enable the organization at large. This activity in return provides an increase in revenue and profits.

Computer technology is intended to make business operate more efficiently; it is often intrinsically complex to manage. That is because the functional form characterizing the relationships between technology investments and organizational performance of the firm is unknown[94]. The benefits provided by technology projects are complex in nature, and can consist of various intangible and non-financial factors, which are not easily measured[95,96]. Great uncertainty is still present within portfolios of IT investments which is why they are considered challenging. They also have a long payback period and affected by the changing business environments (Bardhan et al, 2004)[97]. The project prioritization among IT projects is crucial; this is mainly because IT needs, high costs and IT spending can be identified and are referred to as discretionary. This is exacerbated by the use of political influence by managers looking to have their projects funded, which can lead to a culture where ideas and requests

[92] Daugherty, Patricia J, R Glenn Richey, Stefan E Genchev, and Haozhe Chen. 2005. Reverse logistics: superior performance through focused resource commitments to information technology. Transportation Research Part E: Logistics and Transportation Review 41, no. 2: 77-92.
[93] Keen, PGW. 1991. Shaping the future: business design through Information Technology Harvard Business School Press: Boston, Massachusetts, USA.
[94] Shafer, Scott M, and Terry A Byrd. 2000. A framework for measuring the efficiency of organizational investments in information technology using data envelopment analysis. Omega 28, no. 2: 125-141.
[95] Milis, Koen, and Roger Mercken. 2004. The use of the balanced scorecard for the evaluation of information and communication technology projects. International Journal of Project Management 22, no. 2: 87-97.
[96] Gunasekaran, Angappa, Peter ED Love, F Rahimi, and R Miele. 2001. A model for investment justification in information technology projects. International Journal of Information Management 21, no. 5: 349-364.
[97] Bardhan, Indranil, Ryan Sougstad, and Ryan Sougstad. 2004. Prioritizing a portfolio of information technology investment projects. Journal of Management Information Systems 21, no. 2: 33-60.

progress mainly due to the position and influence of the individuals behind the project proposal. As a result, efficiency of a business can decline over a period of time due to lack of innovation. For example focus may shift towards increased upkeep of old technology, rather than investment in new development and various technological innovations that an organization may need to scale up in the future. Such a reactive approach to prioritization can adversely affect a business's general health in that it can lead to technology departments becoming trapped in a cycle of work where there is no alignment between the work done and business objectives on the whole. Therefore, in the absence of a process that prioritizes projects by linking technology to the strategic objectives, most work and achievements will not align, thereby wasting resources, effort and time. Due to these factors, the commitment of the stakeholders becomes difficult to achieve (Cooper et al, 2003)[98]. IT investments would also fail to meet the strategic objectives due to the lack of communication between the Chief Information Officer and the non-IT executives (Jeffery et al, 2004). Bad investments in the IT portfolio take place when the organization does not contain a centralized over view. This also causes the development of redundant applications (Jeffery et al, 2004)[99]. There exists clear evidence that the IT Portfolio management mechanisms must be implemented.

The portfolio of an organization's IT investment is the specific IT related mechanism known as the IT Portfolio Management (IT PM) (Fitzpatrick, 2005)[100]. During the previous decade, portfolio management has been widely used to conduct IT projects[101,102]. (McFarlan, 1981) is considered to be the first to propose a portfolio management approach to IT assets and investments. According to his theory, projects are the components of the portfolio and not the

[98] Cooper, Robert G, and Scott J Edgett. 2003. Overcoming the crunch in resources for new product development. Research-Technology Management 46, no. 3: 48-58.
[99] Jeffery, Mark, and Ingmar Leliveld. 2004. Best practices in IT portfolio management. MIT Sloan Management Review 45, no. 3: 41.
[100] Fitzpatrick, Edmund. 2005. IT portfolio management: Maximizing the return on information technology investments. Economics Corporation, Gaitherburg, Maryland, United States of America.
[101] Kersten, Bert and Han Verniers Han. 2004. Managing IT as portfolio. Informatie, November: 64-69.
[102] De Reyck, Bert, Yael Grushka-Cockayne, Martin Lockett, et al. 2005. The impact of project portfolio management on information technology projects. International Journal of Project Management 23, no. 7: 524-537.

investments or the assets. This contribution is widely recognized and provides the categorization of projects in different project types with each type of project demanding a distinct management effort, such as: external integration, internal integration, formal planning. The business outcomes of the business can be achieved in an effective manner if the collective management of these unrelated projects is carried out. The overall risk of the organization is also reduced as much as possible[103]. The business outcomes which have been taken into account by (McFarlan, 1981) do not remain constant and are subjected to changes due to technological, social, economic, political and legislative issues. The portfolio of IT investments content has been described as a collection of information regarding IT investments. Within the IT portfolio, each significant IT asset is described along with its outsourcing contract, license, use of IT, business activity, project, program and initiative (Fitzpatrick, 2005). Functionality is contributed greatly by the IT program and it is able to provide support for a unique product or objective of the organization. Individual projects are present within this program and have their own ability to provide unique functionality. In a study presented by (Fitzpatrick, 2005) portfolios of IT investments have been divided into two different assets. First is the IT projects and secondly the ongoing IT activities[104]. The ongoing IT services refers to the repetitive and ongoing operations carried out upon the existing organizational IT services. It is a temporary endeavour to conduct projects as they have a beginning and an end[105]. We now discuss an example of portfolio management by (Schwalbe, 2010) where single portfolio exists for the organization as a whole and this activity is not considered an easy task as illustrated in Figure 10 below. At an enterprise level, top management is required to analyze total portfolio. The management of projects of each sector are further improved by breaking down the portfolio

[103] McFarlan, F Warren. 1981. Portfolio approach to information-systems. Harvard business review 59, no. 5: 142-150.
[104] Fitzpatrick, Edmund. 2005.IT portfolio management: Maximizing the return on information technology investments. Economics Corporation, Gaitherburg, Maryland, United States of America.
[105] Archer, Norm P, and Fereidoun Ghasemzadeh. 1999. An integrated framework for project portfolio selection. International Journal of Project Management 17, no. 4: 207-216.

components into categories[106].

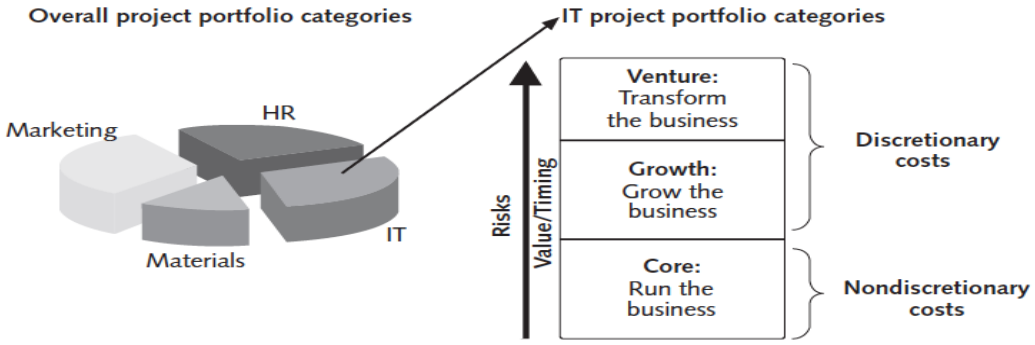

Figure 9 Project Portfolio Categories (Schwalbe, 2010)[106]

The above example shows that there are 3 categories of IT project portfolios: (1) The business is transformed through the projects in the venture category. The activity includes breaking into new ventures, markets, acquisitions, mergers, application package, outsourcing etc. (2) The organization is expected to grow with the projects in the growth category as the revenues would expand the scope of operations of the organization. These projects may include the addition of incremental capacity, upgradation of software and several other efforts. The core category projects helps keep the business operational. (3) The projects include the maintenance projects, utilities, operational activities or disaster recovery initiatives. The right section of the figure shows that non-discretionary costs are present within the Core category of IT projects. The organizations are required to fund these costs no matter what the circumstances are. Discretionary costs are present for the Venture or Growth category as it is the decision of the organization to fund them or not. The middle arrow has been labeled as Risks, Value/Timing. This arrow indicates that as the organization moves from the Core to the Venture projects, the time, value and risks increase. Some core projects may also prove to be of high value, high risks.

[106] Schwalbe, Kathy. 2010. Information technology project management. Cengage Learning

Chapter 3 : Decision Support Systems (DSS)

Ideally, the assessment of project proposals depends on the impact they generate. Therefore it is vital to have the capacity to make structured decisions, evaluate alternatives and perform calculations to determine priorities so as to be able to carry out effective project prioritization, or project portfolio selection, using a selection procedure. These abilities should be ingrained in the methods being used; therefore, to make good decisions, it is vital to be able to carry out measurements and explain those measurements[107].

3.1 Expectations vs. Reality

Researchers are often constrained in overly simplifying the underlying assumptions towards evaluating the issue under consideration. The conclusion often observed relates to the potential users ignoring the existing research literature and continuing with simplistic economic processes as discussed in chapter 4 or even proceeding in an organized process. A relevant aspect to be considered is that irrespective of whatever methodology adopted, it can seldom account for all the aspects concluded in real life scenarios, as reflected in the table 1 below. This table (Souder et al. 1986) expressed some of the factors contributing to the majority of management models not necessarily reflecting the full spectrum of complexities observable in real world scenarios. Thus, the assumptions concluded in classical scientific models are stated in the left hand column and the actual scenario is detailed in the right. There are major differences observable, explaining the constraints of the various models[108].

[107] Bible, Michael J, Susan Bivins, and Susan S Bivins. 2011. Mastering project portfolio management: a systems approach to achieving strategic objectives. J. Ross Publishing.
[108] Souder, William E, and Tomislav Mandakovic. 1986. R&D project selection models. Research Management 29, no. 4: 36-42.

Table 1 Expectation vs Reality [108]

Assumptions when developing models	**Real world environment**
There are single decision makers within a standardized environment	There are multiple decision makers within an ever changing environment
It is possible to have all aspects of the information regarding the candidates, their values, the risks and the outputs	It is not possible to quantify complete information regarding candidates, their values, the inherent risks, and there are multiple uncertainties associated therein
Known, invariant goals	Ever-changing fuzzy goals
The decision maker concludes what is to be done single-handedly, keeping all information within themselves	The decision making process involves the coordination and synchronization of multiple aspects and levels within the entire organization
The decision maker is able to articulate all the consequences	The decision maker is often unable or unwilling to state outcomes and consequences
Candidate projects are viewed as independent entities, to be individually evaluated on their own merits	The projects are considered to be economically and technically interdependent
A single objective, usually expected value maximisation or profit maximisation is assumed and the constraints are primarily budgetary in nature	There are sometimes conflicting multiple objectives and multiple constraints and these are often non-economic in nature
In consideration of economic factors, an optimum portfolio is decided upon	Various non-economic factors would affect the final mix of the portfolio selected
Budgetary processes are optimized in consideration of a single decision	Iterative and re-cycling processes are adapted to decide upon the budget

While there may be multiple selection methodologies and evaluation criteria, there is no single standardized process describing how the task could be conducted with optimum efficiency. It is therefore a complex process regarding how projects are considered, and this

aspect should be considered, although all-encompassing models are hard to come by (Meredith et al, 2003)[109].

However, the challenge in utilizing models relate to the fact that real-world issues are often overlooked towards ensuring the simplicity of the models considered. Besides, the relevant models proposed in literature are often overlooked in favor of simplified financial processes discussed later. These simplified processes in turn are not cognizant of the various complexities associated and involved with the processes. At times, even when a more updated model is perhaps used, the same is discontinued when the initiator of the process adopted leaves the organization.

3.2 Minimum Viable Methodology

Associated academic literature describes minimalistic conditions in deriving a workable methodology. Fundamentally, the multiple criteria evaluating the various project proposals bring in complexities in evaluating the processes. Thus, scalable processes do provide some respite in this regard towards how the alternatives are to be prioritized [110]. Sophisticated evaluation processes consider various details in this regard [111]. These characteristics consider the complexity of the related prioritization processes, with more complex methodologies required for resolving and aligning conflicting viewpoints with regard to key decisions [112]. Sophisticated processes consider increases in the quantum of time required when concluding objective decisions. To this end, aspects of consistency and simplicity are seemingly crucial since they contribute towards ensuring that the benefits from the efforts expended are in

[109] Meredith, Jack R, and Samuel J Mantel Jr. 2011. Project management: a managerial approach. John Wiley & Sons.
[110] Karlsson, Joachim, Claes Wohlin, and Björn Regnell. 1998. An evaluation of methods for prioritizing software requirements. Information and Software Technology 39, no. 14: 939-947.
[111] Azar, Jim, Randy K Smith, and David Cordes. 2007. Value-oriented requirements prioritization in a small development organization. IEEE software 24, no. 1: 32-37.
[112] Maiden, Neil A, and Cornelius Ncube. 1998. Acquiring COTS software selection requirements. IEEE software 15, no. 2: 46-56.

proportion and synchronization to the input made. Thus, it is seemingly important that the methodologies adopted herein are not time consuming and are instead efficient towards making decisions. It is also vital to note that when projects are being carried out, a consistent, objective technique is offered by the method of prioritization so as to determine the projects that are not going to be selected when a higher priority project requires additional resources or a necessary project is included in the pipeline. For instance, after the capital planning has been carried out for the present year and projects are chosen, if a single project is going behind the prescribed time because of which it needs further resources, it is ensured through effective prioritization that when such decisions are made, there is a explicit reason why the project is important.

In the perception of (Turochy et al, 2006), objectivity in project selection is highlighted by two significant elements, namely defensibility and rationality. The term, defensibility, is derived from "defensible" implying lucidity of data so defensibility provides the prospect of assessment of apparent data by stakeholders with whom they can evaluate the procedure and assure the precision of the decisions are in compliance with guidelines. Rationality is the combination of sequential steps in contemplation of avoiding any injustice or the involvement of any political power. Project selection will be strengthened with the presence of rationality in approach, as it will then enable the independent authorities to consider and re-evaluate the entire system. They further insisted that project selection is such a procedure in which decisions can be rightly taken on the basis of project attributes rather than political influence and this aspect creates an environment of accountability[113]. That being said as per (Power, 2004) rationality also comes with its own limitations arising from cognitive, environmental and behavioral

[113] Turochy, RE, and JR Willis. 2006. Procedures for prioritizing proposed transportation improvements at the metropolitan level. Transportation Research Board 85th Annual Meeting.

decision-making models[114]. One such limitation according to (Brindle, 1999) is the perception of what is rational as being taken for granted or hard to dispute. This limitation occurs due to the decision making trap of framing[115]. This factor has been described as (Druckman, 2001) as, "A framing effect occurs when different, but logically equivalent, words or phrases (e.g., 10% employment or 90% unemployment) cause individuals to alter their decisions."[116]. A potential alternative is framed to be taken for granted or as hard to dispute, resulting in strong and fast commitment behavior from decision makers towards that alternative to be undertaken[117]. (Simon, 1960), uses his model of bounded rationality to explains the process of satisficing which explains that human beings possess cognitive limitations that do not allow them to search for an optimal solution perfectly and independently and make them satisfied with what they have attained; rather Simon suggested that decision makers choose the first alternative that is good enough or satisfies choice criteria[118]. Economist's model of rational decision-making put forwardby (Forman, 2001) in which a sequence of logical steps has been followed and need all the defined knowledge, criterion with an absolutely definite issue[119].

In addition, findings of previous studies demonstrate that the manner in which data is expressed creates certain decision biases that bring about disagreements in a group decision-making situation[120]. It has also been found in research that prioritization methods that have been developed for a specific situation can play a major role in decreasing disagreements that can emerge between decision makers in situations requiring mutual agreement. In situations where disagreements between decision-makers do occur, innovative thinking is required regarding

[114] Power, D. 2006. How do decision-making models relate to the design and use of DSS?. http://dssresources.com/faq/index.php?action=artikel&id=21.
[115] Brindle, Margaret. 1999. Games decision makers play. Management decision 37, no. 8: 604-612.
[116] Druckman, James N. 2001. Using credible advice to overcome framing effects. Journal of Law, Economics, and Organization 17, no. 1: 62-82.
[117] Brindle, Margaret. 1999. Games decision makers play. Management decision 37, no. 8: 604-612.
[118] Simon, Herbert A. 1960. The new science of management decision. New York, NY: Harper and Brothers.
[119] Forman, Ernest H, and Mary Ann Selly. 2001. Decision by objectives: how to convince others that you are right. World Scientific.
[120] Hutchinson, J Wesley, Joseph W Alba, and Eric M Eisenstein. 2010. Managerial Inferences: The Effects of Graphical Formats on Data-Based Decision Making Heuristic and Biases in Data-Based Decision Making: The Effects of Experience, Training, and Graphical Data Displays. Journal of Marketing Research.47: 4. 627-42.

how information can be presented[121]. The studies also showed that in the practical world, instead of the laboratory setting where biases are typically determined, there are other limitations on rational decision-making, for example as discussed earlier political influence that may minimize the impact of objectivity and rationality when there is prioritization of projects[122]. The basic focus is to reduce the quantum of decision biases highlighted earlier, towards ensuring that the prioritization process is less chaotic and not driven by subjectivity, instinct or gut feelings.

Moreover, the structured approach is adopted when evaluating data involved in the processes, instead of focusing only on aspects of consistency. This refers to ensuring that the conclusions are derived using a systematic and repeatable process. Consistent prioritization processes are on the lookout to detect inconsistencies in how the management concludes various processes, towards ensuring the reliability of the decisions undertaken[123]. It should also be ensured that the prioritization methodologies adopted are consistent and broadly applicable to different scenarios. Thus, should a specific methodology be considered too narrow, it could lose the element of cross-functionality in comprehensively comparing the various elements and situational paradigms involved. A pertinent methodology would therefore relate to general comparisons vis-à-vis the various associated alternatives. Thus, the conclusions derived should be acceptable to the stakeholders involved, be cognizant of prevailing accounting methodologies, and ensure that the conclusions derived are verifiable. Further, it is important that the selection criterion is uncomplicated to the extent possible (Kengpol etal., 2001)[124]. The broad parameters of the selection criteria are evaluated in the context of technology selection by

[121] Power, DJ. 2005. Can computerized decision support systems impact, eliminate, exploit, or reduce cognitive biases in decision making?. DSS News 6, no. 20.
[122] Turpin, Marita, and Niek du Plooy. 2004. Decision-making biases and information systems. Proceedings of the 2004 IFIP International Conference on Decision Support Systems (DSS2004): Decision Support in an Uncertain World. Prato, Tuscany. 782-92.
[123] Karlsson, Joachim, Claes Wohlin, and Björn Regnell. 1998. An evaluation of methods for prioritizing software requirements. Information and Software Technology 39, no. 14: 939-947.
[124] Kengpol, Athakorn, and Christopher O'Brien. 2001. The development of a decision support tool for the selection of advanced technology to achieve rapid product development. International Journal of Production Economics 69, no. 2: 177-191.

(Torkkeli et al., 2001)[125]. It is therefore indicative of the fact that the prioritization methodology is highly dependent on the context involved.

The mathematical methodologies developed therefore incorporate multiple aspects of the complexities involved, and as the models incorporate an increasing number of these aspects there are proportionate requirements for the data. Considering that the major portion of the information so available is considered non-quantitative, the models are correspondingly taken to be non-linear and subsequently impractical. Besides, the decision makers often have all the required information on-hand, which entails a consensus amongst the various individuals involved in aligning their varied goals, divergent information and associated viewpoints. In consideration thereof, perhaps only a structured environment is capable of ideally fulfilling the data requirements towards concluding an effective consensus. The approach considers the analytical advantages of utilizing mathematical processes, reflected in terms of better communication processes and improved cooperation among decision makers.

3.3 DSS for Project Prioritization

BOGSAT is the widespread method used to come up with complicated decisions and refers to 'a Bunch of Old Guys/Gals Sitting around Talking (Figure 11) [126]. Poor measurement methods and inadequate collaboration activities impede BOGSAT decisions, and in addition lead to futile discussions. One of the main reasons why BOGSAT is not a successful decision making tool is that it has been determined by psychologists that the human brain is limited to distinguishing up to approximately seven things, and in the short term, it can only recall more or

[125] Torkkeli, Marko, and Markku Tuominen. 2001. Use of GDSS in technology selection: experiences and findings. System Sciences, 2001. Proceedings of the 34th Annual Hawaii International Conference on. IEEE. 1

[126] Bible, Michael J, Susan Bivins, and Susan S Bivins. 2011. Mastering project portfolio management: a systems approach to achieving strategic objectives. J. Ross Publishing.

less seven things (Miller, 1994)[127]. To state it more simply, we are able to recall around seven numbers in the order they have been told to us and can distinguish or explain only seven things, such as seven musical tones, with each sound being related to a letter or number. However, several aspects are involved in business decisions, for instance "… issues, pros, cons, objectives, criteria …" (Forman, 2001)[128]. Some of the typical examples of BOGSAT with respect to project prioritization include the scenario where the first project proposal that is received is worked on till there is a decline in funds and resources. Similarly, only the total cost and time span of the project is taken into account and when these aspects are smaller for any project, it is selected as it will be profiled as a low risk and so, these examples can also be referred to as the reactive approach. The benefit of this technique is that there is high level of motivation among the decision makers as they are working on their preferred projects. In contrast, strategic goals and planning are essentially not considered. Decisions can also be influenced by top management's political pressure. Acceptable levels of risk have to be justified through project payouts and those projects that are deemed to be quite risky should be eliminated. In case a firm decides to work on a family of products, all prospective projects should be assessed with respect to their complementarity - their strategic conformity to the current product lines or their capacity to enhance the existing product family.

[127]Miller, George A. 1994. The magical number seven, plus or minus two: Some limits on our capacity for processing information. Psychological review 101, no. 2: 343.
[128]Forman, Ernest H, and Mary Ann Selly. 2001. Decision by objectives: how to convince others that you are right. World Scientific.

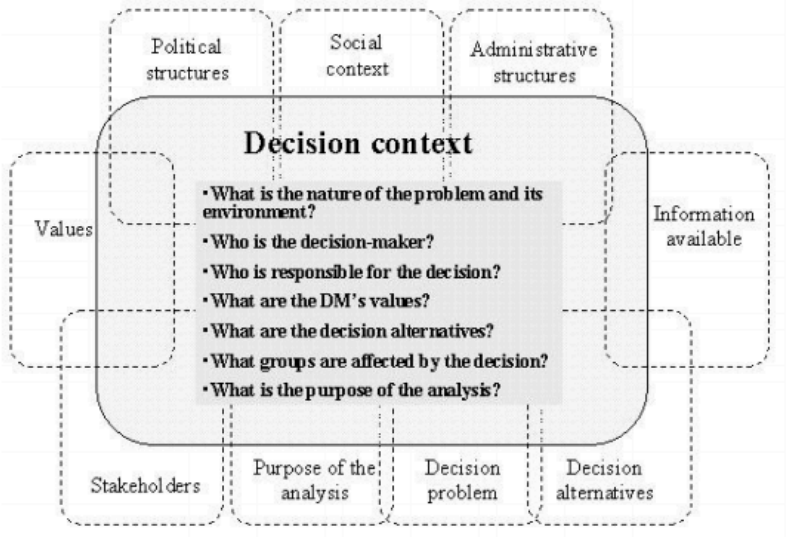

Figure 10 Decision Context (Goodwin et al, 2004)[129]

Figure 10 is a rough sketch of complexities involved in such decisions (Goodwin et al. 2004)[129]. The value-focused thinking approach of (Keeney, 1992) provides several valuable suggestions, which can lead to the identification of decision opportunities and the creation of better alternatives[130].

Judgment errors and biases are the main reason behind organizations choosing the wrong projects. It is important for decision makers, especially managers, to understand what the concept of decision support constitutes when it comes to the prioritization process, not just the workings of a tool itself. Decision makers must be more involved in the development, customization and the criteria for prioritization decisions inputted into their decision support tools. They need to be able to provide input and feedback into the process and methodology and should be aware of all existing methodologies that offer different ways of approaching the problem to be solved. Also important is that decision makers need to become fully knowledgeable of both the upside and downside associated with using DSS.

[129] Goodwin, Paul, and George Wright. 2004. Decision analysis for management judgement. 3rd ed. Chichester: Wiley.
[130] Keeney, RL. 1992. Value focused thinking: a path to creative decision making Harvard University Press. Cambridge: Massachusetts.

In addition, there are two other aspects that need to be taken into account with respect to the use of any DSS for selecting the project. Firstly, the most comprehensive model developed is still merely a partial reproduction of organizational reality. There are actually endless possibilities of factors that can become part of any prioritization decisions; to the extent that we need to understand this reality before project selection takes place, in case we mistakenly presume that it is likely, considering sufficient time and effort, to recognize all related factors. Secondly, there are objective as well as subjective factors that are included in each decision model. We are likely to develop opinions on the basis of objective data and we may obtain intricate decision models from subjective inputs. Therefore, it needs to be recognized that a place for subjective and objective inputs and decisions exists in any valuable framework[131].

As discussed, the human brain is prone to make certain errors when making choices from a psychology perspective. Several studies in business and psychology journals have revealed that a multitude of different biases and thinking traps exist. These biases and traps warp human judgment, thereby introducing inaccuracies into human estimates and forecasts, which lead to making the wrong decisions. A DSS helps guard against and minimize certain biases and traps. Therefore, decision makers also need to know about decision support systems as an important tool that supports decision-making, which in return facilitates organizational processes[132]. Thus, knowing the consequences of leaving decision making biases and traps unchecked can help one to recognize the importance of decision support systems. Without the backing of such tools, the decisions made regarding which projects to choose, will be systematically biased.

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[131] Pinto, Jeffrey, K. 2010. Project Management: Achieving Competitive Advantage, Second Edition. Published by Prentice Hall.

[132] Keen, Peter. 1980. Decision support systems : a research perspective."Cambridge, Mass. Center for Information Systems Research, Alfred P. Sloan School of Management.

3.4 Advantages and Disadvantages of DSS

Research shows that DSS provide users and organizations several advantages[133], yet there are also certain disadvantages to using them, especially when they are used improperly or inappropriately[134]. Some of these advantages and disadvantages are listed in Table 2 below.

Table 2 Advantages and Disadvanatges of DSS

Advantages	Disadvantages
1. Time Savings 2. Enhanced effectiveness. 3. Improved environmental scanning. 4. Facilitation of interpersonal communication. 5. Competitive advantages. 6. Overall cost reduction. 7. Promotion of learning and training. 8. Increase in decision maker satisfaction. 9. Solidification of consensus among decision makers. 10. Increased organizational control. 11. Increased transparency. 12. Automation of the managerial process. 13. Improved consistency and clarity in decisions.	1. Over emphasis on decision making and losing sight of the end aim. 2. Assumption of relevance simply because a DS tool is being used. 3. Transfer of power and feeling of status loss to DS tool. 4. Unanticipated effects such as potential reduction in human decision making skills. 5. Obscuring of responsibility by potentially blaming the DS tool in case of problems or errors. 6. False belief in one's own objectivity simply because the DS tool is objective. 7. Information overload.

[133] Power, Daniel J. 2007 "What are the advantages and disadvantages of computerized decision support?" Decision Support Systems Resources. N.p. 2 <http://dssresources.com/faq/index.php?action=artikel&cat=2&id=130&artlang=en>.
[134] Ibid

The first 7 advantages to decision making help with organizational effectiveness and strategy, as explained in the Michael Porter article "What is Strategy?" [135] Advantages 8 to 11 work to increase accountability and ethical decision-making [136]. Benefits 12 and 13 are related to achieving more decisiveness through the use of models and automated decision-making [137], which helps to reduce the downside associated with intuition based decision-making [138]. Ultimately, all these benefits to decision making from using DSS help towards reducing uncertainty. The three kinds of uncertainty in decision making that DSS can help with most are Level 1 uncertainty (an almost clear future), Level 2 uncertainty (alternative futures) and Level 3 uncertainty (a range of futures). However, DSS may not be helpful when it comes to Level 4 uncertainty (absolute uncertainty, i.e. there is no idea whatsoever as to what the future will bring). As decision making uncertainty decreases, decisions become more accurate, consented to and, thus, beneficial for the organization[139].

[135] Porter, Michael E. 1996. What is strategy. Harvard Business Review November-December: 59-78.
[136] Marchand, Donald A, William J Kettinger, and John D Rollins. 2000. Information orientation: people, technology and the bottom line. MIT Sloan Management Review 41, no. 4: 69.
[137] Tenaglia, Mason, and Patrick Noonan. 1992. Scenario-based strategic planning: A process for building top management consensus. Planning Review 20, no. 2: 12-19.
[138] Schoemaker, Paul JH, and J Edward Russo. 1993. A pyramid of decision approaches. California Management Review 36, no. 1: 9-31.
[139] Courtney, Hugh, Jane Kirkland, and Patrick Viguerie. 1997. Strategy under uncertainty. Harvard business review 75, no. 6: 67-79.

Chapter 4 : Project Evaluation Methodology

4.1 Financial Methods

Conventional financial methods that involve cost/benefit analysis essentially seek to evaluate the economic impact of a proposed project. These methods help determine the expected return on the basis of cash-flow estimates of several project variables that are frequently related to one another. There is uncertainty regarding these project variables, which gives rise to risk. It is important to carry out a risk analysis that backs investment decisions by providing decision-makers with a measure of the variance that is linked to the project return estimate[140]. Net Present Value (NPV) is the most frequently employed technique that converts the cash flows of a project into a single value, written in the form of present monetary value. This allows for carrying out comparisons between early and late values in the same cash flow streams and also between cash flows that have varying income and expenditure profiles. Using NPV, projects can be compared using various revenue and expenses streams. The primary issue pertaining to the use of NPV is that the cash flows for technology projects are not quite predictable and employ a consistent discount rate over time. The time taken by various projects or technologies to recover the preliminary capital outlay is determined using the Payback period (PP). The discounted payback technique is beneficial in the sense that it permits determining the time required to meet the preliminary project investment in a more "intelligible" manner. Hence, for accounting purposes, simple payback is valuable, but discounted payback provides a more clear demonstration of financial realities that need to be taken into account by all organizations in their respective projects. The impact of inflation and forthcoming investment prospects play a role in individual investment decisions and therefore, they should also play a

[140] Savvides, Savvakis. 1994. Risk analysis in investment appraisal. Project Appraisal 9, no. 1: 3-18.

role when assessing project opportunities[141]. The discount rate that decreases the NPV of a cash flow profile of a project to zero is represented by the internal rate of return (IRR). A project is deemed to be better during project selection when it has a higher IRR which shows that the project is going to attain payback sooner. This method is considered to be advantageous compared to NPV because it does not require estimations of future interest rates; rather, it requires estimating the future cash flows of the project.

With respect to technology assessments, significant drawbacks are related to the use of financial methodologies. For instance, prospects can have a negative NPV when calculated on their own; however, they may offer an option to introduce future value-added services and different technological innovations that may be required for scaling the organization's operations in the future. It is possible that financial models may be biased in the short term and do not allow comparison of various options against the status quo[142]. It is also not easy to acquire data like investment expenses, gross income, expenditure, depreciation, interest rate and salvage value, even though this information is vital for carrying out calculations at the point technology projects are evaluated. Because of the different risks involved in IT investments, it is not easy to obtain the discount rate. Examples of such risks are estimation risk, project risk, technical risk, internal risk, systematic risk and external environment risk. A higher discount rate accounts for the risk in the methods discussed earlier. However, traditional analysis methods are unable to provide a measure of discount rates in IT projects[143]. It happens quite often that financial analysis, and subsequently the ownership, are to be managed by the finance department, while other departments are taking decisions on various issues like the amount of

[141] Pinto, Jeffrey K. 2010. Project management: achieving competitive advantage. Second Edition. Upper Saddle River, NJ, USA: Pearson/Prentice Hall.
[142] Carter, William K. 1992. To invest in new technology or not? New tools for making the decision. Journal of Accountancy 173, no. 5: 58.
[143] Milis, Koen, and Roger Mercken. 2004. The use of the balanced scorecard for the evaluation of information and communication technology projects. International Journal of Project Management 22, no. 2: 87-97.

money that should be spending, when to spend that money and on what. This leads to a poor alignment within the organization regarding profitability contributions of project portfolio selection.

Financial models are crucial and need to be taken into consideration with other methods so that a suitable business decision can be made. However, these models concentrate only on the time periods employed in discounting cash flows. There is a high degree of optimism inherent in financial methods that can vary quite dramatically across the project's lifecycle because of external and internal factors. However, because there are extensive advantages inherent in IT projects as discussed as highlighted, they are frequently difficult to justify solely on the basis of financial analysis. Therefore, it is important to consider flexibility by involving more than a single criterion so that decision makers can justify technology project investments by presenting a more precise representation of strategic business value nonfinancial factors that may involve a longer-run view of the costs and benefits of a project.

In light of drawbacks associated with financial methods, multi-criteria models discussed in the subsequent sections, are favored as they represent an organization's strategic objectives more accurately, without giving up on long-term efficiency for financial advantages in the short run. However, there are certain proposals that need complex financial proof of their feasibility. On the other hand, others may require presenting just an acceptable profile compared to other alternatives. This suggests that the methods discussed earlier may be suitable under specific situations. Here, it can be asserted that the prioritization process should not leave out the crucial, non-financial criteria. The core idea here is possibly to select an algorithm that is comprehensive enough to include financial as well as non-financial aspects for analyzing information technology projects.

4.2 Multi Criteria Decision Making Problem

The alignment of strategic organizational goals with proposed initiatives undertaken is considered the convergent approach, wherein the decision makers within the company set out the strategic goals of the firm and detail the broad parameters in this regard. (Machavarapu, 2006) has noted that the process of prioritization must consist of a top down approach where the business strategy is broken down into measurable performance measures, which act as evaluation criteria[144]. Considering that instituting a uniform criterion is a challenge in such a scenario, multiple methodologies have been accordingly proposed in consideration of the interests of the various stakeholders involved. This research therefore considers a multi-criteria decision making problem (MCDM)[145]. A MCDM problem refers to various criteria in evaluating decision-making processes[146]. (Salinesi et al, 2006) has described a structured framework as displayed in Figure 11 below, which can act as a guide for this process[147].

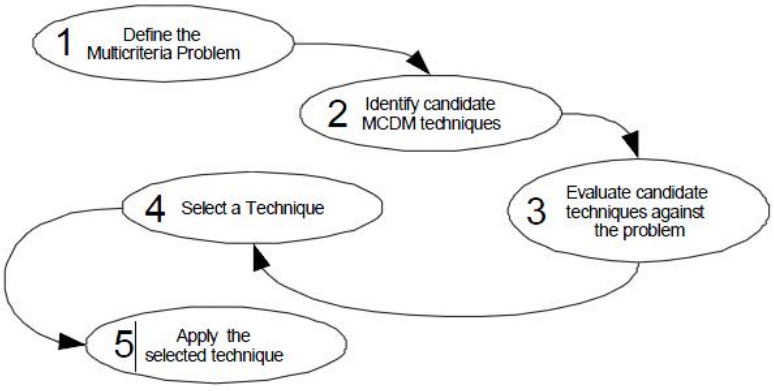

Figure 11 Selecting of MCDM Technique (Salinesi et al, 2006) [147]

[144]Machavarapu S. 2006. Steps to Prioritization: Too many IT projects are based on bogus cost savings projections rather than business strategy. Here's how to link project prioritization directly to value." CIO. 19 (19): 1.
[145] Clayton, R. 1971. A Convergent Approach to R&D Planning and Project Selection," Research Management. Vol. 14, No. 5: 68-75.
[146] Köksalan, M Murat, Jyrki Wallenius, and Stanley Zionts. 2011. Multiple criteria decision making: from early history to the 21st century. World Scientific.
[147] Salinesi, Camille, and Elena Kornyshova. 2006. Choosing a Prioritization Method-Case of IS Security Improvement. CAiSE Forum.

Therefore one must make a distinction in the type of multi criteria problem involved. We try to systematically evaluate and break down the problem as is illustrated in figure 12 taken from (Doumpos et al. 2002)[148].

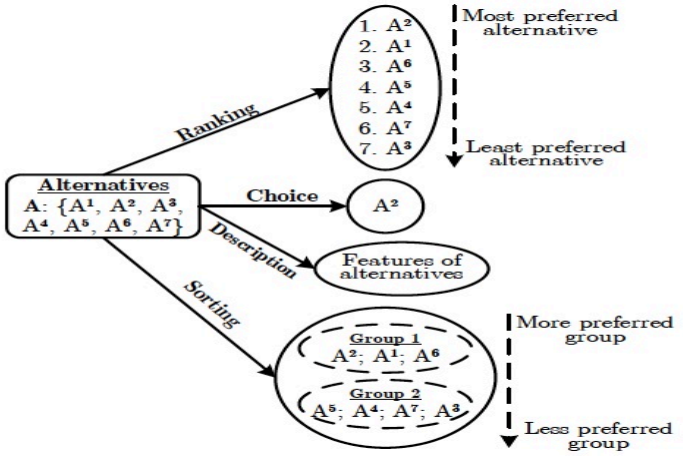

Figure 12 Prioritization Problem Classifications (Doumpos et al, 2002) [148]

Initially, screening reduces the number of alternatives so effort is focused upon options likely to be considered. StageGate Process helps in this process; multiple gates are employed at each stage of a funnel where a decision is made whether to continue investing in the project (a go/Kill decision). These gates serve as check posts with respect to quality of execution, evaluate business rationale, evaluate risk and reduce uncertainty and approve the project plan and resources. (Edgett, 2015) stated that the six strategic factors given below are used to screen the projects to critical few[149]:

1. Strategic Fit and Significance
2. Product and Competitive Edge
3. Attractiveness of the Market

[148] Doumpos, Michael, and Constantin Zopounidis. 2002. Multicriteria decision aid classification methods. Vol. 73. Springer Science & Business Media.

[149] Edgett, Scott J. 2015. Stage-Gate Model overview http://www.stage-gate.net/downloads/wp/wp_10.pdf

4. Core Competencies Leverage
5. Technical Viability
6. Financial advantage compared to risk.

When the problem pertains to ranking, the options available are ranked from best to the worst on the basis of their unique measure of performance that has been obtained. In contrast, when sorting is the problem, the various options are grouped into categories or elements of project portfolios along with those that are similar as per the evaluation criteria deployed. These groups should be ranked from the best to the worst because if the groups are not ranked in this manner, the issue turns into a categorization problem. (Wheelwright et al, 1992) developed a matrix called the aggregate project plan. Based on the extent of product change and process change, they identified four separate categories of projects as Derivative projects, Platform projects, Breakthrough projects and R&D projects[150]. Similar idea was presented by (Cooper et al., 2007) where they also categorized projects in four categories and placed them in buckets with new products, platforms and technology developments, Improvements, modification and extension and finally customer requests. They also stated that four types as different than each other as stocks are from bonds and advised the use of different evaluation criteria for individual buckets[151].

For choice problems, it may not be necessary to give comprehensive evaluations of all possible alternatives, because some inferior alternatives are not worth further consideration such as a home selection problem, which is not the focus of this thesis. Selection is going to generate issues of limited resources, time deadlines, risks, etc. Lastly we include the post implementation process as a final phase of prioritization process, as described using Project Portfolio

[150] Wheelwright, S and K. B. Clark. 1992. Creating Project Plans to Focus Product Development," Harvard Business Review: March–April.
[151] Cooper, RG. 2006. 10 Ways to Make Better Portfolio and Project Management Selection Decisions http://www.stage-gate.net/downloads/wp/wp_24.pdf.

Management Framework in Chapter 1.

The key aspect is to assess project proposals and prioritize them for implementation on the basis of their significance. Here, there is no single method that is absolutely ideal; however, it is vital to comprehend different outlooks towards prioritization so that a customized technique can be adopted that makes the process consistent and transparent and enables the provision of more measurable decisions. The effectiveness of a decision in how projects are prioritized is only reflected over a period of time. To this end, the success lies is the reliability of the data regarding the cost and benefit factors involved, the complex trade-offs between multiple objectives, risks and constraints.

Performance criteria used to evaluate projects need to be constantly updated due to the fast changing environment and any modifications in business priorities need to be precisely reflected. Moreover criteria need frequent recurring input and involvement of several stakeholders involved. It is also important that all project proposals are correctly aligned under the generally accepted prioritization criteria therefore, contribution from different business domains is needed, including not just the customers, but also the senior management and executive representatives in important areas like sales, finance, IT, and various lines-of-business. These individuals are typically in the most suitable position to explain the greatest business priorities of the firm. This input would serve as the basis for lower-level functional and technical specifications that are later outlined in project or portfolio. In addition, when there are several criteria for assessment, a lot of effort will be required and decision makers may end up overlooking their duties by becoming involved in pure speculation.

Once the extensive field of information system benefits have been identified, the information economy principle for assessing benefits of IT related proposals is performed to ensure that less tangible issues are taken into account[152]. The tangible measures consist of customer service enhancement, customer development, churn rate, improved competitive edge, and so on as one must make an important distinction with respect to project attributes related to cost, time, skills and resources pertains to project management constraints not project performance measures. In addition, there are intangibles that cannot be calculated easily in terms of the dollar value. For instance, technological innovation, competitor response, sustainability, etc. It is also determined through information economy whether advantages and risks are included as two distinct parts; i.e. business and technology. Quantifying investment benefits in information technology would not be easy when these two aspects are taken into account[153].

The alternatives can be contrasted along an identical scale, when a series of shared evaluation criteria are defined that should be analyzed and provided along with project proposals that have been put forward for selection. This would also enable apples to apples comparison between them. In addition, it would make administrative processing simpler, which is critical when there are several proposals that cannot be compared easily as they span across various operations. This can only be attained when the alternatives are evaluated with respect to the aims and objectives of the organization.

[152]Milis, Koen, and Roger Mercken. 2004. The use of the balanced scorecard for the evaluation of information and communication technology projects. International Journal of Project Management 22, no. 2: 87-97.
[153]Martinsons, Maris, Robert Davison, and Dennis Tse. 1999. The balanced scorecard: a foundation for the strategic management of information systems. Decision support systems 25, no. 1: 71-88.

4.3 Performance Measures

Michael Porter's Strategic Adaptation approach asserts that investments in IT should be capable of generating competitive advantages. The role of technology in attaining a competitive edge is essentially comprehended with the help of Porter's value chain. This tool plays a valuable role in aligning IT investments with organizational objectives. This association between organizational objectives and IT should justify performance measures of IT projects[154]. Project activities should be positively related to the expected outputs, consequences and outcomes. A series of theorized causal links assumed to be true by the one submitting the project proposal is the basis of these relationships. This will exhibit the way these cause-and-effect relationships function amidst a group of intermediate stages that start with project activities and conclude with project outcomes. When the performance measures are supervised by pre and post analysis, it is validated whether these theorized relationships have taken place and whether they took place at the same level as was expected. This compels the decision makers to assess the crucial presumptions that form the basis of project design and examine the extent to which they are justifiable. This kind of discrepancy would be explained through a model that explained the logical relationships between project activities, outcomes, effects and outputs. The significance of these efforts has been backed through research. It was reported by (Ittner et al., 2003) that those organizations that establish a causal business model on the basis of performance measures present considerably greater returns on assets and returns on equity in the five-year time periods compared to those that do not do so. Three advantages of this process have been recognized: improved internal communication with respect to strategic presumptions, improved recognition and calculation of strategic value drivers, and enhanced resource

[154]Milis, Koen, and Roger Mercken. 2004. The use of the balanced scorecard for the evaluation of information and communication technology projects. International Journal of Project Management 22, no. 2: 87-97.

allotment and target-setting[155].

It is clear that a business model needs to be established to provide a guideline for the establishment and selection of performance measures. A heuristic logic is generated by a successful business model that links the technical expertise with the attainment of economic worth[156]. According to (Osterwalder et al, 2005), the Business Model was the blueprint of the way business is carried out[157]. The business model in (Slywotzky, 1996) words it as follows: 'the completeness in the way the company chooses its customers, explains and distinguishes its product offerings, explains the tasks it is going to perform on its own and the ones it is going to outsource, arranges its resources, reaches the market, establishes utility for customers and collects profits'[158]. According to (Mayo et al., 1999), the business model is the "development of critical interdependent systems that establish and maintain a competitive business'[159]. Hence, decision makers need to expand their perspective to determine the correct business model or 'system of the revenue' so that technological value can be captured. When companies are unable to do so, the technologies are going to give lesser value to the firm compared to what they would otherwise[160]. It is evident that a business model cannot be created in any fixed manner. Tangible advantages are normally easier to describe compared to intangible benefits; and this can be done with a degree of ingenuity. Even though non-financial measures are significant to some extent, there are risks inherent in them. Hence, it is vital to make efforts to quantify intangible benefits in terms of numbers, percentages or currency.

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[155] Ittner, Christopher D, and David F Larcker. 1998. Are nonfinancial measures leading indicators of financial performance? An analysis of customer satisfaction. Journal of accounting research 36: 1-35.

[156] Chesbrough, Henry, and Richard S Rosenbloom. 2002. The role of the business model in capturing value from innovation: evidence from Xerox Corporation's technology spin-off companies. Industrial and corporate change 11, no. 3: 529-555.

[157] Osterwalder, Alexander, Yves Pigneur, and Christopher L Tucci. 2005. Clarifying business models: Origins, present, and future of the concept. Communications of the association for Information Systems 16, no. 1: 1-40.

[158] Slywotzky, Adrian J. 1996. Value migration: how to think several moves ahead of the competition. Harvard Business Press.

[159] Mayo, Michael C, and Gordon S Brown-. 1999. Here's one option for building a newer, more competitive business. Ivey Business Journal 63, no. 3: 18-23.

[160] Chesbrough, Henry, and Richard S Rosenbloom. 2002. The role of the business model in capturing value from innovation: evidence from Xerox Corporation's technology spin-off companies. Industrial and corporate change 11, no. 3: 529-555.

It is relatively easy to quantify the related tangible benefits since they lead to more efficient use of resources as described in chapter 2. Correspondingly, (Marchewka, 2003) argues intangible benefits are also identifiable although they are often a challenge to quantify effectively, and would require the creativity of the evaluator. This area is open to further research. Nevertheless, it is always important to summarize the benefits concluded in this regard. A pertinent methodology would be to associate intangible benefits with tangible aspects towards measuring the efficiencies accrued[161]. (Gliedman et al., 2004) offers the perspective that individual projects should be evaluated against present business conditions, and how they impact the overall organizational goals[162]. Thus, while costs are perhaps far easier to quantify in comparison to the advantages accrued, nevertheless significant budget elements within IT initiatives are often intangible and it has been concluded that over 40% of all IT related costs are hidden and cannot be quantified[163]. A pertinent example would be software assets, which would be periodically upgraded but would nevertheless fail to fulfill the considerations foreseen. (Rigatuso, 2005) is of the perspective that in calculating the cost of an IT project, the periodic up-gradation element or maintenance cost should also be factored in and should be an important consideration, although this is, nevertheless, open to debate[164].

Towards ensuring that the prioritization process is not bereft of accountability or transparency, it is important that there are certain criteria associated with the process. These should be tangible, measureable and observable whenever required. Further, benchmarking is a corresponding factor, which should be considered part of the equation to compare the various options considered and later actuals can be compared with predictions. In setting forecasts and

[161] Marchewka, Jack T. 2003. Information technology project management. John Wiley & Sons,
[162] Gliedman, Chip. 2004. Defining IT Portfolio Management. Forrester. Best Practices. Cambridge, MA: Forrester Research.
[163] Milis, Koen, and Roger Mercken. 2004. The use of the balanced scorecard for the evaluation of information and communication technology projects. International Journal of Project Management 22, no. 2: 87-97.
[164] Rigatuso, C. 2005. Project portfolio analysis for internal IT. Redwood Shores, CA: Oracle.

then comparing with the actual results, provides a good measure of the direction of the entire effort. Therefore, if the parameters set are not observable, it would be a challenge monitoring the progress of the input and perceiving the imperfections concluded therein. Besides, the proposals associated with a project also provide a measure for correctly perceiving the performance contracts. Towards ensuring the effective and efficient utilization of limited resources within a firm or a company, it is important for project requestors to clearly define the objectives to be achieved through the effort. Thus, considering the entire initiative as a performance contract enables optimizing the decisions on how the project is to be executed, and enables a better perspective on the aspects which should be focused upon.

Forecasting and estimating are key aspects to be considered in correctly evaluating the uncertainty associated with determining project performance; hence, performance measures are not required to be things that are observable at present. For example, measures can involve a projected future state of certain observable event, such as an enhancement in reliability-of-service, which is required for customer satisfaction. In consideration of the various uncertainties, it is often a challenge to correctly forecast events. Thus, it is important that the progress of the task being executed is periodically measured since over the course of its execution, a few parameters would be observed to be exceeded while some aspects would need further input. Correspondingly, this enables the company to understand the various uncertainties involved and therefore a chance to recalibrate the decision model to incorporate lessons learned which would improve the forecasts moving forward.

At times intuitive performance measures are deemed to be unavoidable and more often, the clairvoyant test indicates significant inaccuracies in aspects which otherwise seem well-defined and otherwise clear-cut. The concept of the clairvoyant test (clarity test) is useful in

decision analysis for ensuring clarity of thought, particularly when assessing uncertainty by evaluating how well elements of a decision making model are defined (Howard, 1988). Clarity test can immensely help when strategic goals are being translated in to measureable performance measures. Thus, oftentimes just the "customer satisfaction" parameter is not considered to be able to meet the requirements of the clairvoyant test. However, in the same context the percentage expressing the reduction in customer complaints and companies ranked according to the industry's customer satisfaction surveys are aspects that are considered to be able to meet the criteria set in this regard[165].

To a certain extent, subjectivity is considered a reason contributing to why firms hire professionals in exchange for their experience. Therefore, the individual's judgment, understanding and intuition regarding the future could be important aspects. Such measures would be often reflective of the processes already widely implemented within the industry. At times, a seemingly straightforward project would entail significant complexities which are not necessarily identifiable within the original proposal of the project, although their importance in this regard cannot be truly impressed upon to the extent desired. At times, certain aspects could be considered necessary, including compliance to regulatory aspects. It is important that much thought is invested in designating mandatory projects so that it does not ultimately hinder the flexibility of the overall initiative, and conclude in the inefficient utilization of organizational resources.

Non-financial performance measures, due to their nature, can more easily become prone to measurement error or manipulation and it is not easy to check them accurately. It has been asserted by researchers from time to time that non-financial measures can turn into a prominent

[165] Howard, Ronald A. 1988. Decision analysis: practice and promise. Management science 34, no. 6: 679-695.

measure of future financial performance. (Larcker et al., 1997b)[166], in his study involving banking and telecommunication companies, reported that customer satisfaction was a significant measure of subsequent financial performance. However, the significance of non-financial objectives relies on the strategic and operating environment of the organization. It was reported by (Larcker et al., 1997) that non-financial measures are highly significant when a company is seeking an innovation strategy (like new ventures that have been found to be cash-flow negative) or a quality strategy (like the execution of total quality management)[167]. These results received the backing of (Said et al., 2003) who found that non-financial measures were used to a greater extent within companies that had adopted an "innovation" or "quality" strategy, companies whose products had long development cycles, companies that were part of a highly regulated industry, and companies facing financial turmoil[168]. It is indicated in these studies that when a company's existing strategy is not focused on short-term financial goals, non-financial measures are extremely significant.

Therefore, performance measures are used to reduce the extent of gaming in terms of 1) strategic misrepresentation and 2) optimism bias. In this setting, the former refers to measures which identify the quantum of bias towards calculating how a certain project would be favoured over others; while the latter refers to the reasons someone would believe themselves to be less liable in case actuals fail to meet forecasts. In considering and comparing forecasts with the actual happenings, individuals would be liable to consider their bias as being an expression of the propensity of the risk involved. Knowing the performance measures involved would enable the company take correct decisions towards achieving the goals and objectives set. The

[166] Ittner, Christopher D, and David F Larcker. 1998. Are nonfinancial measures leading indicators of financial performance? An analysis of customer satisfaction. Journal of accounting research 36: 1-35.
[167] Ittner, Christopher D, David F Larcker, and Madhav V Rajan. 1997. The choice of performance measures in annual bonus contracts. Accounting Review: 231-255.
[168] Said, Amal A, Hassan R HassabElnaby, and Benson Wier. 2003. An empirical investigation of the performance consequences of nonfinancial measures. Journal of Management Accounting Research 15, no. 1: 193-223.

following (Table 3) are a few aspects that could be considered by decision makers when relying on performance measures: [169]

Table 1 Performances Measures [169]

Sensitivity	This refers to the extent to which an action would be responsive to corporate and management input. It enables evaluating the extent to which a particular strategy is functioning, besides evaluating the quality of the work completed.
Precision	This concludes the extent of errors liable to be inclusive within the calculations, and how much the calculations are susceptible to manipulation.
Verifiability	It is important that the parameters considered are independently audited and verified towards assuring the accuracy of the information concluded.
Objectivity	This measures the objective, like the number of accidents accrued, or involves subjective measures like how much employees are considered committed to the organizational cause. The various measurement paradigms have similarity with regard to aspects of precision, sensitivity and verifiability towards measuring the entire aspect considered.
Dimension	This refers to how the conclusions are measured, i.e. whether they are expressed in percentage terms, within a survey scale, as a function of how many times the event has occurred, or in terms of a binary outcome. It also evaluates whether metric lend itself to different interpretation if expressed in a different manner this provide a common language for communication.
Interpretation	This refers to the aspect which evaluates the outcome. It could therefore relate to whether the product failure rate indicates the manufacturing quality, or whether it would be perhaps indicative of the quality of the design involved. It would therefore relate to the characteristics of the owner, the quality of the data involved, the measurement unit, the results to be concluded, the frequency at which the values are noted, or the associated thresholds.
Cost	It evaluates whether the tracking the metric provides accurate and commensurate value for money against the effort invested in the project.

[169] Larcker, David, and Brian Tayan. 2015. Corporate governance matters: A closer look at organizational choices and their consequences. Pearson Education.

4.4 Multi Criteria Decision Making Theory

The various factors impacting decision making processes contribute to enabling the decision maker decide on specific options to be considered in consideration of various conflicting consideration (Yoon et al, 1995)[170]. Thus, the prioritization process considered in lieu of the Multi Criteria Decision Making paradigm is often valid in information technology-based organizations and involves multiple decision-making aspects. There are decision rules undertaken vis-à-vis MCDM which are classified into two groups (Hogarth, 1987; Bible et al, 2011) [171,172]

- Strategies related to how conflicts are tackled in consideration of choices made
- Strategies undertaken to resolve conflicts

The strategies detailing how conflict is to be resolved are compensatory which mean that low value aspects could be traded off with corresponding higher values. This could be justified in how x units of attribute i could be considered compensatory or replaceable against y units of the j attribute. However, conflict avoiding strategies are considered to be inherently non-compensatory which are bereft of the trade-off aspect (Hogarth, 1987)[173].

Compensatory decisions are considered rational requiring complete identification with regard to the multiple attributes negatively or positively impacting the alternatives considered, evaluating the attribute with regard to its importance, valuation of options in the context of the model, and concluding the process in consideration of the best value. Thus, in the context of compensatory decisions, the final values concluded would entail the negative attributes to be

[170] Yoon, K Paul, and Ching-Lai Hwang. 1995. Multiple attribute decision making: an introduction. Vol. 104. Sage publications.
[171] Hogarth, Robin M Robin M. 1987. Judgement and choice: The psychology of decision. New York, John Wiley & Sons.
[172] Bible, Michael J, Susan Bivins, and Susan S Bivins. 2011. Mastering project portfolio management: a systems approach to achieving strategic objectives. J. Ross Publishing.
[173] Hogarth, Robin M Robin M. 1987. Judgement and choice: The psychology of decision. New York, John Wiley & Sons: 72

compensatory by the higher values associated with the positive attributes considered. To illustrate, comparable airline tickets to the same destination costing $50 more is considered a negative attribute. Nevertheless, this could be considered to be a more preferable in consideration of it being a direct flight, which would be the positive attribute (Straub, 2003)[174]. Thus, multidimensional challenges could be similarly broken down to uni-dimensional issues. However, non-compensatory models exclude the possibility of such trade-offs. Cost benefit models are considered valid compensatory models and is referred by classical economists in the context of project evaluations. The central axiom of the cost benefit approach in project evaluation is that every impact of the project must be expressible in monetary terms. Therefore, while a problem could entail varying attributes, the selection among the same units could be considered to be uni-dimensional in the context of the concluding analysis conducted. The plus point associated with multi attribute analysis is that it is able to consider the varying aspects of divergent but related criteria, even while the same could not necessarily be quantifiable, which is specially valid in the context of externalities and intangible aspects. In consideration of the multi-dimensional compromises undertaken, multiple alternatives could be considered in relation to the multi-attributable methodologies. The most common multi attribute methodology would be subsequently evaluated.

There are normally two varying compensatory approaches in terms of absolute and relative assessment methodologies. The former evaluates the various alternatives in lieu of criteria translated to rating scale using utility curves and step functions for determining thresholds (Bible et al, 2011)[175]. Relative assessment methodologies compare the various alternatives within themselves in consideration of pair-wise or direct priority input

[174] Straub, Kath. 2003. Decisions, Decisions … What's a Poor User (and Designer) To Do. Human Factors international. http://www.humanfactors.com/downloads/oct03.asp

[175] Bible, Michael J, Susan Bivins, and Susan S Bivins. 2011. Mastering project portfolio management: a systems approach to achieving strategic objectives. J. Ross Publishing.

methodologies[176]. (Hogarth, 1987) associates the linear compensatory model as being the most comprehensive strategy, which was also seconded by (Van Delft et al, 1977) in consideration of the compensatory changes, which are considered in the context of classical economic utility theory and traditional cost benefit analysis[177,178]. As already explained, in consideration of information technology projects being similarly evaluated as business initiatives, these trade-offs appear to be practical approach in resolving issues in the context of the current study.

(Simon, 1960) demonstrated that every kind of intricate system embraces a hierarchical selection so that the humans can deal with intricacy, as they possess limited cognitive powers[179]. Therefore, the decision-makers are required to prioritize activities in respect with the objectives that prove to be mathematically significant, in case of contrasts with other objectives that are present at the same hierarchy. For example, customer service objective is not as important as the financial objective so it is required to be laid down first. Such priorities are known as ratio-scale priorities. Hence numbers are used as levels of measurement for comparing the importance of objectives and alternatives for complex decision-making.

4.5 Scale of Measurement

After deciding the alternatives (project proposals) and the criteria, it needs to be determined how each criterion would be measured. This would lead to choosing a method to compare the various attributes for each alternative so as to reach an agreement. Therefore prioritization methods are highly reliant on the scale of measurement and the potency of the

[176] Karlsson, Joachim, Claes Wohlin, and Björn Regnell. 1998. An evaluation of methods for prioritizing software requirements. Information and Software Technology 39, no. 14: 939-947.
[177] Hogarth, Robin M Robin M. 1987. Judgement and choice: The psychology of decision:72
[178] Nijkamp, Peter, and Ad van Delft. 1977. Multi-criteria analysis and regional decision-making. Vol. 8. Springer Science & Business Media.
[179] Simon, Herbert A. 1960. The new science of management decision. New York, NY: Harper and Brothers.

scale will determine the best assessments of requests to take place [180]. This scale is assigned by a list of numbers that tell the measurement level and assist in contrasting the relevance of objectives and substitute elements for the sake of concluding difficult decisions. Four measurement scales are identified (arranged in the order of potency): nominal, ordinal, interval and ratio. Every subsequent scale is a combination of inimitable characteristics with the previous scales' characteristics like: the characteristics of interval scale are included in the ratio scale with further characteristics that make ratios evocative. Evaluation and measurement concepts are being discussed because of the fact that measurement is a prerequisite for management. It is generally believed that anything that cannot be measured cannot be planned, controlled or enhanced. According to Albert Einstein, if it is not possible to measure something, then it does not mean it's not important, and there are several important things in the world that are not possible to be measured[181]. There are various definitions and concepts pertaining to evaluation. Traditionally, evaluation refers to the assessment of something's worth in the qualitative and quantitative sense.

The ratio scale embraces a pre-set zero point and the numbers are placed at equal distance in the entire scale. For instance, in the interval scale, if we consider the example of time as ratio scale, the difference between 3hrs : 6hrs and 9hrs : 12hrs is the same i.e. 3 hours whereas the ratio scale displays 3(2) hours = 6 hours, 6(2) hours = 12 hours = 3(4) hours. Ratio level numbers are not restricted anyhow and they can use mathematical operations in any way and this feature strengthens the decision methods mathematically with the inclusion of accuracy and flexibility (Forman, 2001) [182]. The ratios are subjected as relative and absolute. The ratios can be absolute, as in the example just given of 6 hours being twice as long as 3 hours.

[180]Karlsson, Joachim, Claes Wohlin, and Björn Regnell. 1998. An evaluation of methods for prioritizing software requirements. Information and Software Technology 39, no. 14: 939-947.
[181] Stewart, Rodney Anthony. 2007. IT enhanced project information management in construction: Pathways to improved performance and strategic competitiveness. Automation in Construction 16, no. 4: 511-517.
[182]Forman, Ernest H, and Mary Ann Selly. 2001. Decision by objectives: how to convince others that you are right. World Scientific.

Specifically when the dimensions (area) are calculated of one rectangle. This can be seen in Figure 13:

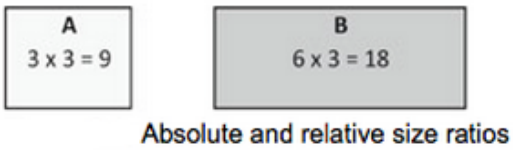

Figure 13 Absolute and Relative Measurement (Forman et al, 2001) [182]

4.6 Analytic Hierarchy Process for Project Evaluation

(Saaty, 1980) formalized a technique, the Analytic Hierarchy Process (AHP) that operates with ratio scales and exemplifies relative assessment so that decision makers can be affirmed and choose the best alternative rationally on the basis of quantitative and qualitative criteria with the assimilation of intuition in their decision approach[183]. Decision making problems that involve distinctive criterions, AHP serves to be an intricate weighted average technique that explicitly rank tangible and intangible determinants unequivocally opposing every other determinant so that pair wise comparison could be made to resolve the conflicts and priorities to be set (Huang et al., 2004; Martino, 2003) [184185]. AHP is an example of a heuristic algorithm. A heuristic algorithm is one that provides good approximate not necessary optimal solution to a given problem. Heuristic is an intuitive rule of thumb for dealing with some aspect of model and algorithm is a step by step procedure for solving a mathematical problem using a computer[186].

[183] Satty, Thomas L. 1980. The analytic hierarchy process New York: McGraw-Hill
[184] Huang, Shi-Ming, I-Chu Chang, Shing-Han Li, and Ming-Tong Lin. 2004. Assessing risk in ERP projects: identify and prioritize the factors. Industrial management & data systems 104, no. 8: 681-688.
[185] Martino, J. P. 2003. Project Selection. In - Milosevic, Dragan Z. 2003. Project management toolbox: tools and techniques for the practicing project manager. John Wiley & Sons..
[186] Moore, Jeffrey H, and Lawrence R Weatherford. 2001. Decision modeling with microsoft excel. 6th edition. Prentice Hall:12-3.

(Forman et al., 2001) indicated three fundamental steps of this procedure; namely, synthesizing (combining), decomposition (structuring), and comparative judgments (measuring). At first, the complex problem is broken down at a granular level and categorized into linked clusters or hierarchies with the decomposition step that works the same as the deliverable work breakdown structure so that commodities for a massive project can be refined. With this option, flexibility is found while incorporating different attributes and/or scenarios are assimilated for a particular criterion. They described the next step as useful because the comparative judgment allows the comparison of relative significance of different elements within the cluster so that it can be related to the parent element of the cluster. With this step, the local priorities of every element can be computed and same principle can be further implemented in every lowest-level sub-objective of different leveled hierarchy when substitutes are regarded with the objectives. Such lowest-level objectives are named as terminal nodes or covering objectives. These covering objectives are found valuable in terms of mapping as the lowest level of the hierarchy, with sub-objectives, is allotted with priorities for every particular sub-objective and then they are aggregated upward to respective parent level. Here, the last step (synthesizing) arises that is performed on the assessment outcomes from which global and local priorities are derived for every element present in the hierarchy of objectives. In a local priority, relative significance of the elements of the group is shown in terms of its siblings. As stated a cluster is formulated with different children present at the same hierarchy level under the same parent and the sum of local priorities will be 1.000 or 100%. In contrast, global priorities are formulated by multiplying parent node's global priority by the node's local priority and the sum of all sibling child nodes of a global priority will be equal to the sum of the parent nodes of the global priority[187]. The figures demonstrate the generic objectives hierarchy in terms of the illustration of global and local priorities when a deride assessment has been done to the sample

[187] Forman, Ernest H, and Mary Ann Selly. 2001. Decision by objectives: how to convince others that you are right. World Scientific.

objectives hierarchy comprising of sub-objectives. Figure 14 displays simple decision hierarchy in which its goal and four purposes are laid. The objective-II is sub-proportioned into four sub-objectives and its sub-objective C is further proportioned into a total of two lower-level sub-objectives (Bible, 2011)[188].

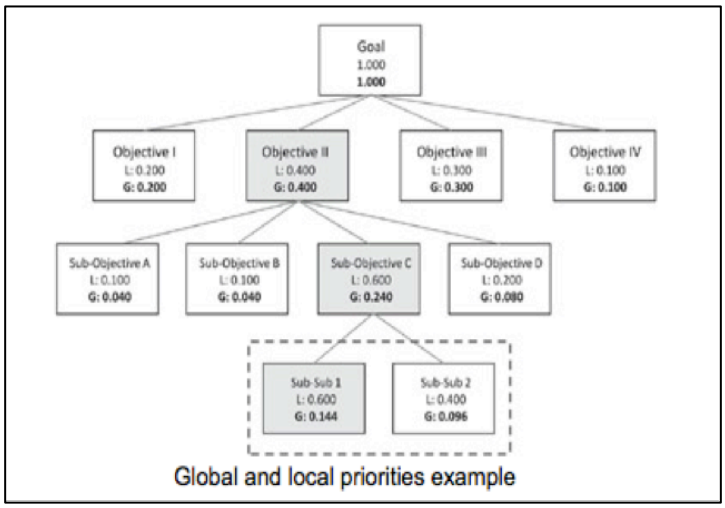

Figure 14 AHP Local and Global Priorities (Bible et al, 2011) [188]

Figure 15 below is practical example taken from (Jeffrey, 2010) [189].

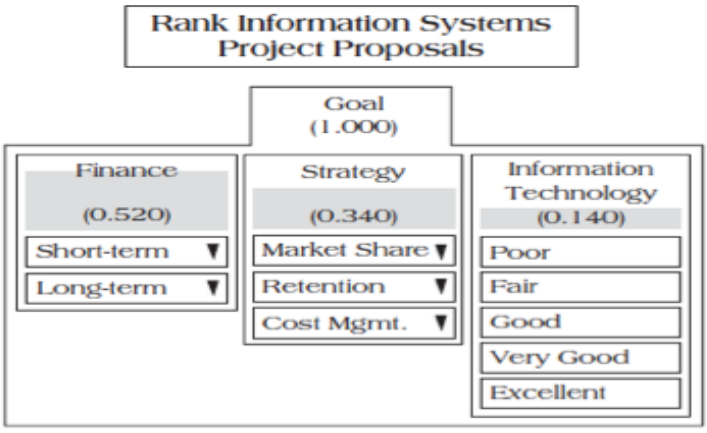

Figure 15 Rankings for Salient Selection Criteria (Pinto, 2010)[189]

[188] Bible, Michael J, Susan Bivins, and Susan S Bivins. 2011. Mastering project portfolio management: a systems approach to achieving strategic objectives. J. Ross Publishing, September 15.
[189] Pinto, Jeffrey, K. 2010. Project Management: Achieving Competitive Advantage, Second Edition. Published by Prentice Hall.

To summarize multi-criteria decision-making is simplified by the AHP in the ensuing ways (Forman, 2008)[190]:

1. Distinctive elements of the problem are structured in a multilevel hierarchy comprising of criteria, sub-criteria, substitutes, and objectives. This is known a structuring the complex problem.
2. The evaluation of the relative preference and significance of the recognised substitutes and objectives correspondingly is performed.
3. The insubstantial forms of information in terms of intuition and experience, and substantial form of quantitative data are assimilated together to originate priorities.
4. The last step of synthesizing is performed with laying the comparison of different viewpoints and competing objectives.

Four axioms are known as the fundamentals of the AHP: homogeneity, correct utilization of AHP indicated by sufficient ideas representation, reciprocal, and absence of feedback in objectives (Saaty, 1980) **[191]**. AHP is comprised of a scale with nine points. The preference of the assessor and ratio-scale degree is found by measuring and contrasting two objectives with each other. The verbal scale comprises degrees between Extremely (nine times as important) and Equal (one times as important) and their differences are found precise like an individual being has made a qualitative comparison as it lies within 7 +/- 2 cognitive limitation and indicate merely single magnitude order roughly[192].

As stated by (Forman, 2001), the fundamental aspect of AHP method is pairwise comparison and the ratio of relative importance, or preference is derived at the time of contrasting elements present in a pair. Such factors may be any of the two determinants of the similar leveled hierarchy and they may be in the order of objectives or sub-objectives and

[190] Forman, E. H. 2008. Project Prioritization and Portfolio Management. Lecture 3 PowerPoint. George Washington University, Washington, D.C.
[191] Satty, Thomas L. 1980. The analytic hierarchy process. New York: McGraw-Hill.
[192] Miller, G. A. 1956. The magical number seven, plus or minus two: Some limits on our capacity for processing information. Psychological Review. no 63 (2): 81–97.

alternatives. Moreover, the ratio is found by subjective judgment using rating scale rather than on a standard absolute scale (meters/minutes). Furthermore, mathematical procedures are utilized for synthesis of results such as proven eigenvectors methodology due to its precision level[193]. This claim was also supported in a study conducted by (Saaty et al, 1998) where several sub methods were explored within AHP and eigenvector method was recommended based on its simplicity i.e. easier to understand and convenient with its effortless mathematical formula. Despite better results being produced by other methods, which required extra effort, there was not much difference in the outcomes and human judgment evaluation is found to be the most erroneous[194]. During pairwise comparison every alternative is being contrasted with other alternative like contrast of A with B, the entire process re-initiates and commences to compare B with A. When this analysis is done in a repeated manner, specifically as the second time initiates, this point is called pairwise comparison diagonal whereas the second set of comparisons is called redundant comparisons. Such a process enables consistency of every assessor and enhances the precision level of the entire assessment using the following formula using λmax which is the sum of each Eigenvector[195]:

$$CI = \frac{\lambda_{Max} - n}{n - 1}$$

Where CI is the Consistency Index and n is the number of evaluated criteria.

To be entirely consistent indicates the maintained level of contrasted correlations for all the judgements included. For instance, Shape A > Shape B and Shape B > Shape C then ultimately Shape A > Shape C. Absolutely consistent choices are indicated by an inconsistency ratio of 0.00. (Saaty, 1986), in terms of axiom of transitivity, stated that if, A = 2B where B = 2C then A = 4C any deviation from this shows the level of inconsistency. When the

[193] Forman, Ernest H, and Mary Ann Selly. 2001. Decision by objectives: how to convince others that you are right. World Scientific.
[194] Saaty, Thomas L, and G Hu. 1998. Ranking by eigenvector versus other methods in the analytic hierarchy process. Applied Mathematics Letters 11, no. 4: 121-125.
[195] Vargas, Ricardo. 2010. PMI Global Congress. http://www.slideshare.net/ricardo.vargas/using-the-analytic-hierarchy-process-ahp-to-select-and-prioritize-projects-in-a-portfolio.

inconsistency ratio is 1.00 then it anticipates the judgments made by chance instead of judgments made intelligently. The inconsistency level is estimated at every judgment set by the AHP and it allows for certain inconsistency level. If the inconsistency ratio is 0.10 or less for the overall evaluator results is considered satisfactory[196]. The decision maker has the prospect of evaluating inconsistencies for every evaluator and combined outcomes with available tools. If the inconsistency is found at elevated rates then it may be assumed that the individuals do not have similar explanations of the elements of the objective hierarchy and a clarification may also be needed. The probability of iteration takes place with high inconsistency or if there is a difference in between the analysis outcomes and intuition; therefore, the facilitator should reassess the outcomes with evaluation participants until mutual agreement is reached.

The reasons for inconsistency are as follows (Forman & Selly, 2001)[197]:

1. Incomplete model structure
2. Accounting error
3. No proper attention paid by the assessor
4. Inadequate information or understanding
5. Practical inconsistency

The judgments will be unsystematic and the inconsistency ratio will be high with inadequate or no information about the aspects compared. Absence of sufficient experience and knowledge is one of the foremost issues faced while selecting assessors (Forman & Selly, 2001)[198].

In the reciprocal axiom, the degree of support (more or less) is judged with the pairwise comparison between Elements A & B. The results indicate that Element B does not support the parent attribute X more than A, further indicating the precision of the reciprocal. Suppose, A = 3B in supporting X then it can be said that B = 1/3A and the same thing is regarded in terms of

[196] Saaty, Thomas L. 1986. Axiomatic foundation of the analytic hierarchy process. Management science 32, no. 7: 841-855.
[197] Forman, Ernest H, and Mary Ann Selly. 2001. Decision by objectives: how to convince others that you are right. World Scientific.
[198] Ibid

significance. Then value of A will be 9 with the values of X and B as 12 and 3 respectively. In terms of homogeneity axiom, elements present in the group of the hierarchy must be equal in magnitude or scale, or else the judgments made may be flawed. Assessors acquire more consistent outcomes with this axiom as there are slighter chances of inconsistency errors like if: A > B and B > C then technically, it should be A > C but they make A < C. For further discussion on AHP axioms, one will need to obtain the journal article of Thomas Saaty (Saaty, 1986)[199].

One of the drawbacks of AHP realized in existing literature is positive reciprocal matrix. Refer to this example, if we take a positive reciprocal matrix, the number 9 is utilized to indicate the value of A where A is found to be of great importance in comparison with B so we can only define the relative significance of B as 1/9 while contrasting with A as we are not left with any other choice. The opinions differ from each other in terms of equanimity. As indicated by (Karlsson et al., 1998) AHP was found to be the most efficient methodology when contrasted with six software requirements prioritization methodologies[200]. The decision is taken by pairwise comparisons in the form of n x (n - 1) ÷ 2 while computing for n alternatives but if we have to considered merely first and second diagonals then we can only use this formula: (n-1) + (n-2). These formulae are also implemented on every such group whose sub-objectives are present in the hierarchy and the total of the no. of comparisons is found to be the same as the total no. of comparisons that has to be proposed.

The ratio-scale priorities for the objectives turn out to be relevant outcomes as they are found to be proportional measures consisting of relative significance of the objectives derived

[199] Saaty, Thomas L. 1986. Axiomatic foundation of the analytic hierarchy process. Management science 32, no. 7: 841-855.
[200] Karlsson, Joachim, Claes Wohlin, and Björn Regnell. 1998. An evaluation of methods for prioritizing software requirements. Information and Software Technology 39, no. 14: 939-947.

from the strategic plan. Keeping organizational goals in mind, the relative priorities of the sub-objectives and objectives are endowed by the assessment of the synthesized outcomes of the objectives. Further, the priorities belonging to the ultimate candidate projects are structured and developed by such prioritized objectives as they give its fundamental conception such that the priorities sustain them in the meantime of the project prioritization procedure. At the same time, the strategic plan is reassessed by further adding up the relative significance of the objectives that are embraced in it. Furthermore, such an assessment is fairly valuable as the IT Strategic Plan is lined up with it, whilst the long-term goals and organizational mission and vision are aligned up with the investments made.

Despite its convenience, AHP is complicated, as there is a direct rise in the necessitated pairwise comparisons as number of alternatives increase. The restructuring of the model may be needed for adding or deducting a sub-objective or objective when any of the group members disagrees with the relative priorities due to the lack of consideration paid to a determinant. Similarly, the assessors may also demonstrate difference in opinions while evaluating objectives or sub-objectives and then the reprioritization could be needed after elucidation. However, AHP have been implemented in vast number of areas. Moreover, there may be required more time by the iterative assessment and options' contrast. As claimed by (Sowlati et al. 2005), as a new alternative is added in the model, the intuitive assessments and comparisons would be required from the commencement and the AHP methodology does not seem to be recognizable or perceptive by numerous people like weighted average scoring model[201]. See the work of (Vargas, 2010) for the full implementation of AHP to rank projects[202].

[201] Sowlati, Taraneh, Joseph C Paradi, and C Suld. 2005. Information systems project prioritization using data envelopment analysis. Mathematical and Computer Modelling 41, no. 11: 1279-1298.
[202] Vargas, Ricardo. 2010. PMI Global Congress. http://www.slideshare.net/ricardo.vargas/using-the-analytic-hierarchy-process-ahp-to-select-and-prioritize-projects-in-a-portfolio.

4.7 Traditional Scoring Models

The Scoring model is found as the most common model if the limitations of the AHP are considered. (Forman, 2001) claimed that alternatives are not contrasted with each other but contrasted to a definite rating scale and more precise decisions are attained with the pairwise contrast when a small amount of alternatives become controllable. However, the utilization of a rating scale is found more convenient in case of large amounts of alternatives in which the consistency of judgments is doubtful due to their sheer number and the pairwise contrasts become burdensome. The assessors feel that the use of rating scale is much convenient in rating the alternatives and tell the supporting level of every alternative along with fulfilling its objectives[203]. Corresponding priorities are also known as intensities in this paper and presented in figure 16:

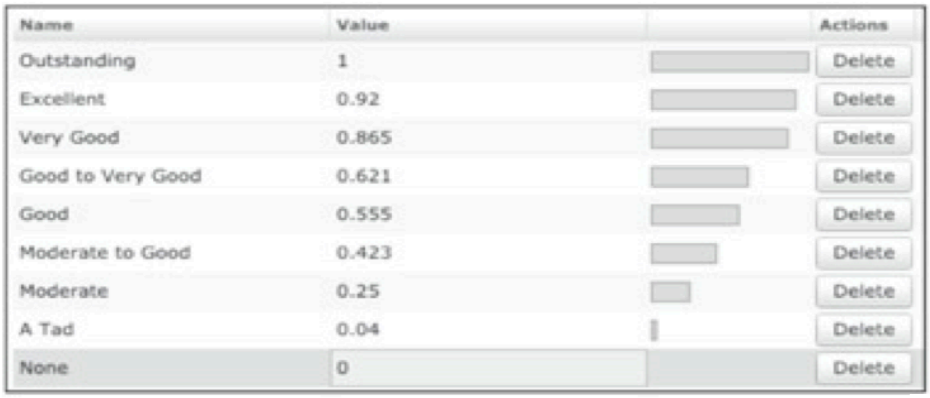

Figure 16 Sample Rating Scale (Bible et al, 2011) [204]

There are a total of nine intensity levels in the aforementioned sample rating scale and everyone is demonstrated by a numeric priority value. It is found beneficial and consistent to originate priority values from the pairwise comparison instead of utilizing arbitrary assignment. Consequently, these priority values are stabilized such that the intensity of the largest priority

[203] Forman, Ernest H, and Mary Ann Selly. 2001. Decision by objectives: how to convince others that you are right. World Scientific.

becomes equal to 1.000[204].

As discussed rating scales can be alternatively used in the place of pairwise comparisons while ratio scale priorities are attained by the translation of familiar information of alternatives in terms of its objective and corresponding decision maker preference and this translation is performed by utility curves; more importantly, only those specific entities can develop translation formulae who possess vast experience. Qualitative and Quantitative criteria are therefore broken down in discrete choices that are then used in assessing the rating scale value of the criteria for a project. The use of discrete choices for criteria and the subsequent translation to numerical values is pre-determined. The criteria can presented on a rating scale from 1 to 100. This allows for qualitative criteria such as risk and intangible benefits and provide a way to account for ambiguity in quantitative criteria as shown in figure 17[205].

Potential risk

Value Decision Maker Chooses	Numerical Value
None	1
Very Low	20
Low	40
Medium	60
High	80
Very high	100

Green dollar costs

Value Decision Maker Chooses	Numerical Value
None	1
Up to $1,000	10
$1,001 to $10,000	20
$10.001 to $20,000	30
$20,001 to $40,000	40
$40,001 to $60,000	50
$60,001 to $80,000	60
$80,001 to $100,000	70
$100,001 to $250,000	80
$251,000 to $500,000	90
Over $500,000	100

Breadth of benefits

Value Decision Maker Chooses	Numerical Value
An individual will benefit	1
An area subgroup will benefit	25
An area will benefit	50
More than one area will benefit	75
The entire division will benefit	100

Figure 17 Tangible and Non Tangible Criteria on Rating Scale (Sowlati et al, 2005)[205]

[204] Bible, Michael J, Susan Bivins, and Susan S Bivins. 2011. Mastering project portfolio management: a systems approach to achieving strategic objectives. J. Ross Publishing.

[205] Sowlati, Taraneh, Joseph C Paradi, and C Suld. 2005. Information systems project prioritization using data envelopment analysis. Mathematical and Computer Modelling 41, no. 11: 1279-1298.

In real conditions calculation of precise numerical value for quantitative criteria is difficult because data at the prioritization stage consists of merely estimates and forecasts. Quantitative criteria can be presented in the form of ranges. Each project could be rated 1 as least favorable and 100 as most favorable for criteria based on profit characteristics (more is less) and 1 as most favorable and 100 as least favorable for criteria based on cost characteristics (less is more) therefore making this an integer-valued data set, dataset values can be comparable by adding or subtracting 100 from either one of the types. For the purpose of translations, pairwise comparisons can be used to derive priority/value at different values of familiar information of criteria. Likewise, an entity can take advantage of step function and this is proven through test grades. For instance, A is scored by 90 to 100 and others till the grade D comes which is scored by 60 to 69 and the grade F is awarded to anyone who attains 60 or less points. The test scores are not based on ratio-scale numbers that means that the 90 points are far better than that of 45 points (unacceptable) not twice as preferable and therefore it is hard to achieve 90 points in contrast with 45 points. Test scores representation done through a utility curve or a ratio-scale step function is more appropriate where none of the value fall below 60 points while those values were attained that display rising trend exponentially so that highest scores can be computed. The pairwise comparisons of the utility/relative values can also be utilized for the origination of rating scale values as shown in figure 20. However, these references represent many other interest-gaining facts of the practical discussion[206,207].

The Weighted Average Method is commonly used with scoring models for computing absolute assessment. It uses a type of value function commonly known as additive function i.e.

[206]Zimmer, D. 2012. What Is the Weighted Scoring Method?. Project Management Terms & Definitions. American Eagle Group. <http://terms.ameagle.com/2011/01/david.html>.
[207] Murty, K.G. 2003. Optimization Models For Decision Making, Dept. of Industrial & Operations Engineering, vol. 1. <http://www.ioe.engin.umich.edu/people/fac/books/murty/opti_model/junior-0.pdf>

weighted sum of distinct attribute value functions. Objective of this approach is to maximize the value across criteria for each alternative. Data generated via scoring alternatives on a rating scale against multiple criteria is the input for this decision model. Subsequently, the assessment of every alternative is done with every criterion, and prior assessments of criteria are used to incorporate decision makers' preference called weights. Resultantly, a general measure is taken to demonstrate the magnetism similar to consumer price index. The way of defining and measuring the criteria distinguish among the scoring models and tells the way of taking out the average of individual evaluations so that a project value score can be attained. These sorts of discrimination influence reliability, information requirements, intricacy, and defensibility of the model. (Forman et al., 1998) notes there are a number of ways present for synthesizing the information described above[208].

When the weights are put on the criteria, a scoring model is said to be a weighted scoring model. It can be mathematically represented as:

$$S_j = \sum_r w_i y_{ij}$$

Total Value Score (S) for *j*th alternative over *N* criteria $(S_j) = w_1(y_{1j}) + w_2(y_{2j}) \ldots + w_i(y_{ij})$

Here, S_j stands for total value score of the *j*th alternative whereas *i* represents the criteria number, N represents the total number of criteria *i*, w_i demonstrates assigned weight to the *i*th criteria (scaling constant) that is allotted to multi-criteria evaluation on the basis of the perception of decision maker and shows the relative significance of a criteria with another. Similarly, s_{ij} represents the score of the *j*th alternative on the *i*th criterion.

$$\sum_{i=1}^{N} w_i = 1 \qquad 0 \le w_i \le 1 \qquad j = 1, 2, 3, \ldots, N$$

[208] Forman, Ernest, and Kirti Peniwati. 1998. Aggregating individual judgments and priorities with the analytic hierarchy process. European journal of operational research 108, no. 1: 165-169.

Finally a constraint that a sum of all the weights w_i is fixed where N is the total number of criteria and value of weight must add up to one. The weight of each criterion can be interpreted as the percent of the total weight allowed for the individual criterion.Weights can quantified by means of the following methodologies: Runoff from the bottom, Runoff from top, English system, swings weight method, American system These methods are elaborated by (Keesey, 1974) and most commonly used AHP methodology as described in the previous section[209]. AHP is advantageous in that only calculating the weights of criteria but not the value scores of the alternatives now reduces pairwise comparisons as illustrated below(figure 20). Data Envelopment Methodology was also used by (Cook etal, 1996) to generate weights. They proposed that explicit values of weights could be obtained by only incorporating decision makers' preferences while optimizing the criteria scores for each alternative relative to the efficiency frontier[210].

Figure 18 is a practical example of weighted average scoring model [211].

Poor 1 (.000)	Fair 2 (.100)	Good 3 (.300)	Very Good 4 (.600)	Excellent 5 (1.000)

	Alternatives	Total	Finance		Strategy			Technology
			Short-Term .1560	Long-Term .3640	Market Share .1020	Retention .1564	Cost Management .0816	 .1400
1	Perfect Project	1.000	Excellent	Excellent	Excellent	Excellent	Excellent	Excellent
2	Aligned	0.762	Good	Excellent	Good	Excellent	Good	Excellent
3	Not Aligned	0.538	Excellent	Good	Excellent	Good	Excellent	Good
4	All Very Good	0.600	Very Good	Very Good	Very Good	Very Good	Very Good	Very Good
5	Mixed	0.284	Poor	Fair	Good	Very Good	Excellent	Good
6								
7								
8								
9								
10								

Figure 18 Sample Project Ratings and Results (Jeffery, 2010)[211]

[209] Keesey, Ray E. 1973. Modern Parliamentary Procedure. Boston: Houghton Mifflin Co: 150-152
[210] Cook, Wade D, Moshe Kress, and Lawrence M Seiford. 1996. Data envelopment analysis in the presence of both quantitative and qualitative factors. Journal of the Operational Research Society 47, no. 7: 945-953.
[211] Pinto, Jeffrey, K. 2010. Project Management: Achieving Competitive Advantage, Second Edition. Published by Prentice Hall.

As per multi attribute theory, preferential independence along with other independence assumptions are required to be held for the implementation of this additive value function as it necessitates the preferences of the decision maker to attain a performance level adjacent to any criterion as it does not rely on the performance attained next to any other criterion. Although convenience is added to the value function by additivity, care is required when defining performance measures for criteria.

Various criteria are seen around scoring models while the criteria sometimes go beyond or reflect linked or comparable objectives while this overlie can result in a number of relevant differences. There must be some constraints imposed on the way of defining and measuring criteria by which errors can be diminished. These sorts of complexities remove the design simplicity as precision was required and this happens to be the main source of attracting scoring models. There may not be the probability of implementation of requisite assumptions and to prove it in a particular setting, however as per decision theory the assumptions hold approximately results generated are close to without simplified assumptions through the use of additive model. This looks like “systematic” but it is found quite intricate to quantify though being convenient for allotment of the weights into every criteria in which the weights must be holding some relative significance. Certain researchers treat weights as subjective, non-reproducible and doubt their transparency and validity of the final scores and rankings.

One of the limitations recognized in regard with these scoring models is that its result is not trusted and regarded as a sound measure of project value. The infeasibility in the project cannot be neglected e.g. the total cost of the project cannot be computed or optimal projects’ portfolio cannot be recognized with the lack of any strong measure of the project value that

deliver the most value for the resources available. Therefore these methods can only be used to rank projects based on their performance/strategic potential but do not allow for selection. The mathematical equation utilized in this standard scoring model is merely able to yield total scores in linear form in which an entire presumption is made; according to this presumption, the project performance is ignored in regard with the same or different criterion and the same amount of unit improvement has been given for the project attractiveness.

Scoring models help to determine whether a project should be initiated or not as they help in attaining a value score for project performance based on strategic goals. Scoring models are the most convenient and easily interpretable as their outcomes are displayed on an ordinal scale as shown in figure 18. Similarly, it is flexible and can be molded according to the organizational preferences/managerial policy or for sensitivity testing using inside and outside perspective described later. On the other side, majority of the scoring models sustain certain intolerant drawbacks. The accuracy of rating scale let's say points of 1-5 is doubtful though it is easily interpretable and applicable. If we will consider it from the mathematical scales, appraisals must not be judged from this scale because of the fact that they represent real number and can be conveniently added or taken out into product. If we consider 3>2 in case if 2 stands for Medium while 3 Stands for High but here the amount is unknown. In the same way, the distinction of 3 & 2 and 2 & 1 is similar therefore ratio scales are recommended shown in figure 18.

Since the act of prioritization is to gain consensus from the majority of decision makers, it is helpful to have some distance between each project value score so that conflicts do not arise. Model in (figure 18) is constrained in that the scores had to be out of 1 (1 being the most preferable). This limits the amount of stretch that can be applied to the range of scores, as the range is bounded in that there cannot be a number greater than 1. Using the unconstrained

model will extend the range of value scores to higher than 1. However, this is still not the complete solution, as the distance between the scores will still remain the same. Fibonacci numbers may be used that can give rise to project overall value scores that are not too close, advantageous especially when ranking proposed projects as total value scores are more far apart which helps in consensus building.

Another reason behind the decision to use an exponential sequence is that the inputs used by the model are merely forecasted estimates at the prioritization stage, and that the use of exponential sequence numbers represents magnitudes that we can intuitively distinguish between. When asking for estimates, presentation options (numeric numbers) that are exponentially apart on a rating scale are particularly helpful as the forecasts get larger and inherent uncertainty increases due to unforeseeable events. This, too, will increase the accuracy of the estimate, which will translate it into more accurate data for model to process. This concept is widely used by the practitioners of agile software development when asking for work estimates. That being said the underlying principle in Fibonacci series is only a mathematical anomaly, and it is not supported in any logical proof or decision-making theory as ratio scales. Moreover a lower value now is far lower then a higher value due to exponential increase embedded in Fibonacci series 1<2<3<5<8 etc..

Scoring models are highly reliant on the criteria chosen along with the weight precision and this serves to be its limitation on the side of managerial policy. No assurance of a reasonable correlation between weighted and selected criteria along with business objectives can be seen as prioritization decisions are based on future[212]. The ease of use of these models is

[212] Project Management: Achieving Competitive Advantage, Second Edition, by Jeffrey K. Pinto. Published by Prentice Hall. Copyright © 2010 by Pearson Education, Inc

favourable to the inclusion of a large number of criteria, most of which have such small weights that they have little impact on the total project score because the output of a weighted model is strictly a relative measure. This is an open research area and calls for advanced techniques to avoid basing all requisite data used on guesswork.

4.8 Visual Presentation

In group decision making, it is important that various participating decision makers reach consensus without undue conflict. Effective presentation of data for decision-making can greatly help reaching a group consensus. This claim is supported by (Hutchinson et al., 2010) showing that the way data is presented can either induce or remove certain decision biases that lead to conflicts in a group decision making setting, especially when the problem is a multi-criteria decision making problem, such as in the case of project prioritization where everyone is after the same limited resources[213]. (Guerlain et al, 2002) detailed how visual data representations are superior to text-based data displays[214]. It is clear that certain kind of value information is processed more effectively using visual displays and graphical input modes than it is processed numerically or vocally (Power et al, 2007)[215]. Data visualization tools help because they offer a straight and intuitive understanding of complex information, and can help in revealing knowledge that is concealed in numbers[216].

[213] Hutchinson, J Wesley, Joseph W Alba, and Eric M Eisenstein. 2010. Heuristics and biases in data-based decision making: Effects of experience, training, and graphical data displays. Journal of Marketing Research 47, no. 4: 627-642.
[214] Guerlain, Stephanie, Greg A Jamieson, Peter Bullemer, and Ronald Blair. 2002. The MPC Elucidator: A case study in the design for human-automation interaction. IEEE Transactions on Systems, Man, and Cybernetics-Part A: Systems and Humans 32, no. 1: 25-40.
[215] Power, Daniel J, and Ramesh Sharda. 2007. Model-driven decision support systems: Concepts and research directions. Decision Support Systems 43, no. 3: 1044-1061.
[216] Keim, Daniel A. 2002. Information visualization and visual data mining. IEEE transactions on Visualization and Computer Graphics 8, no. 1: 1-8.

The scoring model discussed in last section calculates "project value score" based on decision maker's preference over multiple pre selected criteria. This value score is only useful for ranking competing proposed projects for purposes of alignment with strategic goals but is not helpful in identifying optimum project portfolio. On the other hand visual tools can incorporate multiple project portfolio criteria into a single diagram, but are not capable of ranking projects. The project portfolio analysis such as cost/profit analysis, categorizing projects and balancing project portfolio and several other dimensions as explained in Chapter 1 can now be analyzed by visual tools. Which cannot be performed using scoring models alone. Therefore combining results obtained from the scoring model with visual techniques can take advantage of each other strengths. Common visual tools used for portfolio analysis are bubble diagrams and radar charts. Visual project portfolio analysis can be divided into two categories "Inside" and "Outside" perspective.

Figure 19 is the case of outside view where the decision makers want to balance the portfolio over several criteria as per strategic goals of the organization. This way budget contribution can be measured towards each criterion in a given time frame. Moreover, due to changing business conditions decision makers also need to assess how changes in weight for each criterion can affect the positioning of a project portfolio. Consequently affecting the selection of projects because as per Figure 18 sum of weights is fixed i.e. 1 so any increase pushes other to decrease. Figure 19 visualizes this case where increase in criteria E is compensated by decrease in criteria A[217]. As discussed previously the major concern scoring model face in project value calculation is the selection and weighting of evaluation criteria. There is no single way to define these criteria under different circumstances. Having the

[217] PMI. 2013. The Standard for Portfolio Management. Project Management Institute. Third Edition: 101.

flexibility to define a suitable number for weights is crucial; therefore, in that regard radar charts can also assist decision makers to quantify the magnitude of weights.

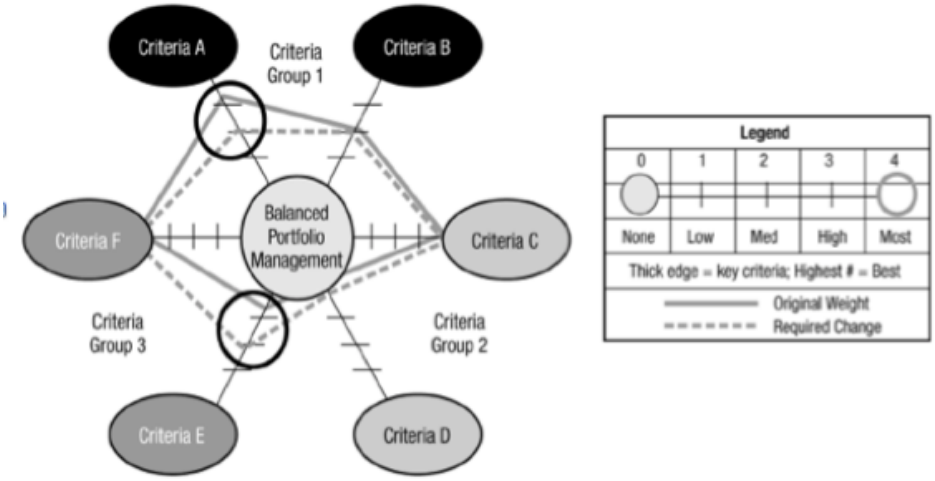

Figure 19 Weighing Business Change (PMI, 2013)[217]

Scoring models can benefit further from radar charts. The center of the radar represents a value of zero with values increasing along each axis towards the circle's perimeter. Proposed project can be scored for each criterion along the appropriate axis and result plot can be compared with other projects under consideration. The relative importance i.e. weights of each criterion (scaling factor) determines how much increase is required on each axis. This also allows decision makers to compare and contrast several proposed projects on the same chart e.g. in Figure 20 radar chart shows 10 criteria to score projects[218]. Radar chat illustrated in figure 21 allow decision makers to set targets for each criterion and evaluating and eliminating projects against them[219].

[218] Mello, Sheila, Wayne Mackey, Ronald Lasser, and Richard Tait. 2006. Value innovation portfolio management: Achieving double-digit growth through customer value. J. Ross Publishing: 97.
[219] PMI. 2013. The Standard for Portfolio Management. Project Management Institute. Third Edition: 101.

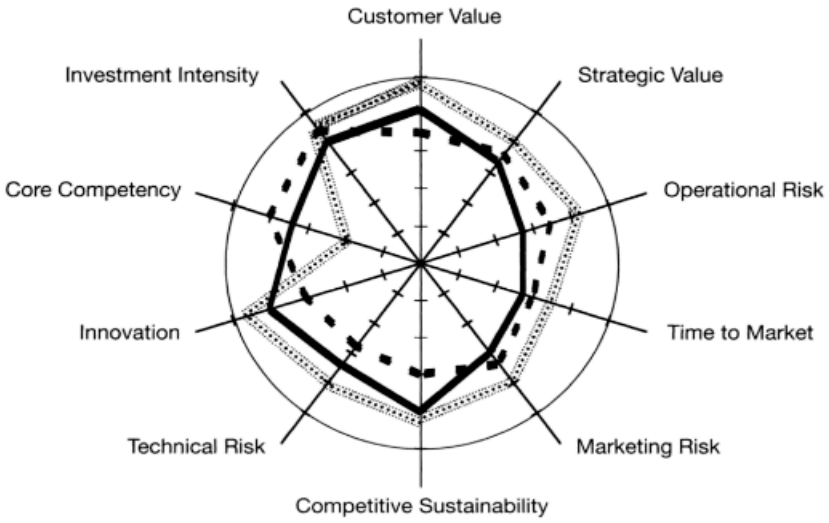

Figure 20 Comparison of different Project Profiles (Mello et al, 2006)[218]

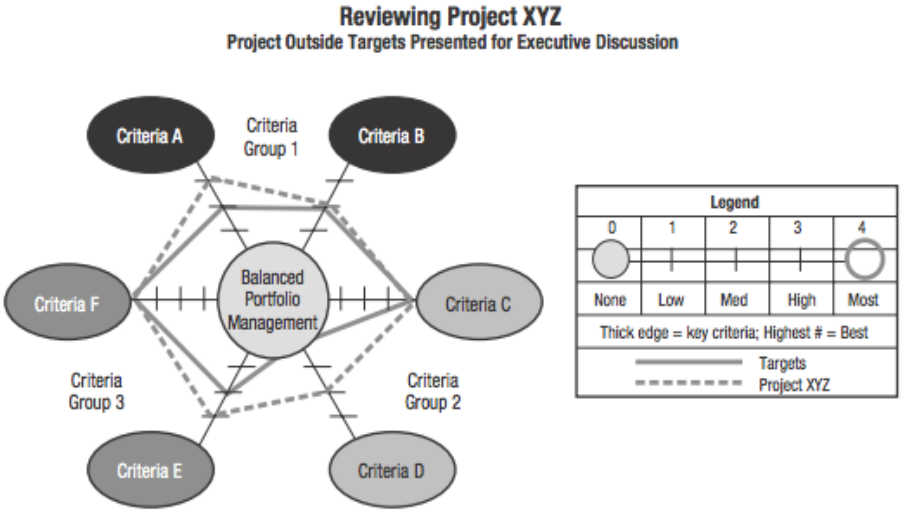

Figure 21 Scoring Component Performance (PMI, 2013)[219]

Below are creative examples of how data can be visualized when evaluating Project Portfolios from "Inside" perspective. As these criteria are used in the scoring models as shown in figure 18 one may then refer to figure 22 where traditional cost vs. benefit analysis can also be performed along side scoring models[220]. Projects with lower cost, higher profit and with greatest value score are lucrative. Figure 23 allows for more criteria simultaneously with the help of software on x, y & z axis using three dimensional space with bubble size representing

[220] Data, Machines. 2011. How to Prioritize Projects. http://www.bubblechartpro.com/content/how_to_prioritize_projects.php.

proportional value score which acts as fourth dimension and color of bubble as fifth dimension identifying the development phase for the analysis of a project portfolio. Identifying optimum project portfolio decisions can be effectively aided as now in this example they consist of projects that would be in upper/front/left quadrant with highest radius[221]. This is the analytical advantage of data visualizations inconsideration of inside view.

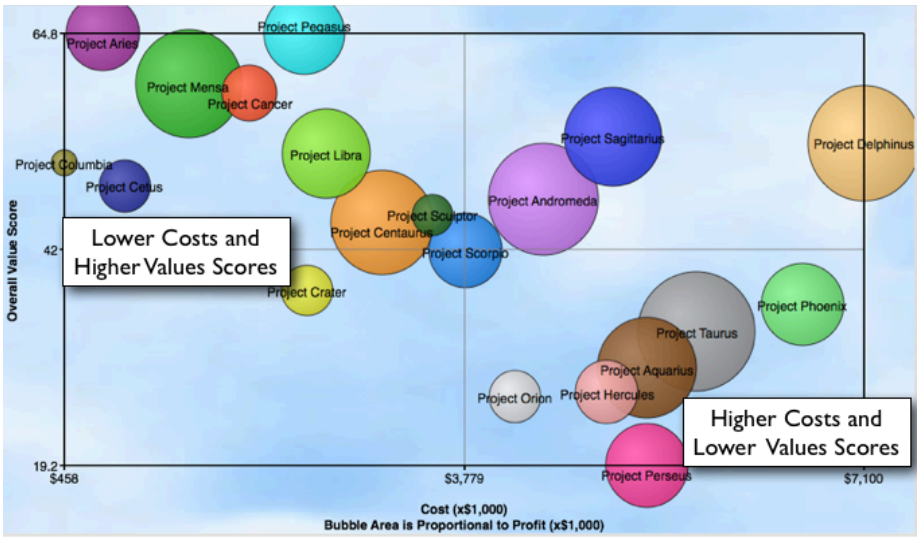

Figure 22 Three Dimensional Project Portfolio Visual Analysis (Data, 2011)[220]

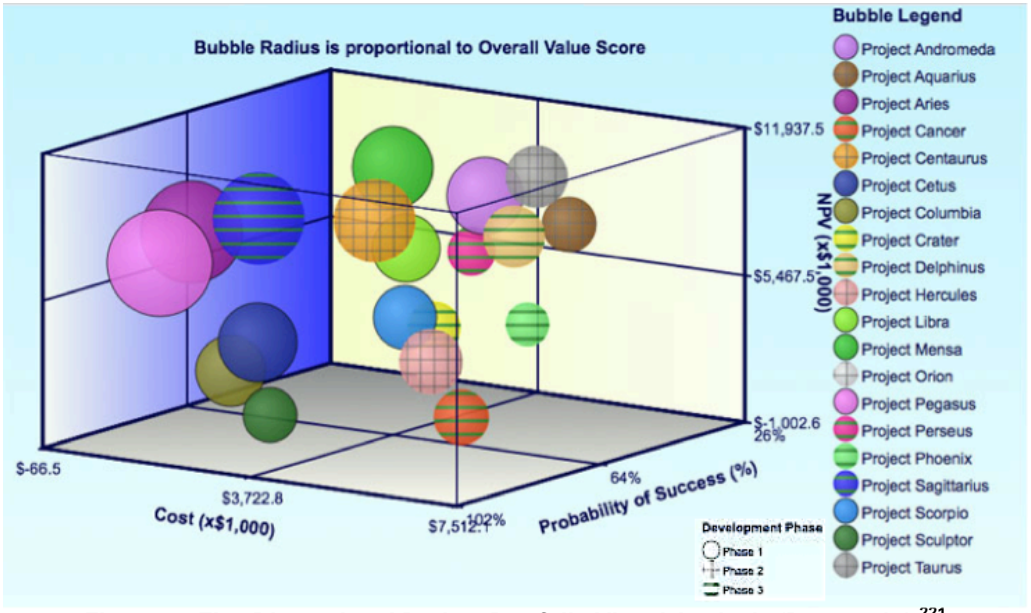

Figure 23 Five Dimensional Project Portfolio Visual Analysis (Data, 2013) [221]

[221] Data, Machines. 2013. Most Valuable Chart in Project Portfolio Management. http://www.bubblechartpro.com/the-most-valuable-chart-in-project-portfol-management/

4.9 Sensitivity Analysis

Given that prioritization is not an easy executive decision process, and its significance cannot be neglected, there may be value added by iteration. Iteration must be given sufficient time in the process schedule. When there has been a radical change in the organizational strategy then this fact seems very true. During the conversations with the existing respondents, appraisals are made through discussions and elucidations. For this the presence of all the respondents is required at the same time no matter what the setting and time zone considered. Such respondents are considered as significant drivers for carrying out the process. The roles and responsibilities can be re-evaluated and interpretation of items can be made in this iteration. The decision makers are now able to judge the derived outcomes by validating whether priorities are generated whose expected contributions were correlated with the goal and specific objective correspondingly[222].

Sensitivity Analysis helps assess how the alternative projects performed against the objectives under different scenarios or iterations[223]. Aspects of sensitivity analysis therefore explores the extent to which the conclusions derived are stable under small changes and whether there is added value in iterating the prioritization process (Forman, 2010) [224]. This could therefore arise within situations where minor changes are being implemented for a few objectives under consideration. Another reason could be if it is recognized that the evaluation process has misrepresented an objective in comparing the associated alternatives and considering low risk scenarios.

[222] Bible, Michael J, Susan Bivins, and Susan S Bivins. 2011. Mastering project portfolio management: a systems approach to achieving strategic objectives. J. Ross Publishing.
[223] Forman, Ernest H, and Mary Ann Selly. 2001. Decision by objectives: how to convince others that you are right. World Scientific.
[224] Forman, E. H. 2010. The Analytic Hierarchy Process. Unpublished manuscript, George Washington University, Washington, D.C.

Sensitivity testing is currently conducted in two ways: dynamic analysis and performance analysis. Dynamic sensitivity analysis considers the immediate impact on the alternatives considered by changing the weighting of decision makers' priorities associated with the objectives also studied using radar charts in previous section. If any single factor is emphasized by increasing its weight, the relative importance of the other factors is correspondingly decreased. Dynamic sensitivity could therefore be illustrative of the priorities associated with the secondary objectives. For example figure 20 shows three main criteria and each criterion is further divided into sub criteria with their own priority weights. Here sensitivity testing considers the impact of sub criteria weight changes on alternative overall score. Finally, performance sensitivity analysis evaluates the overall score of the alternatives during any set of modifications to their score on each individual sub criteria[225]. Figure 24 and 25 are creative examples of dynamic and performance sensitivity testing, presented visually[226].

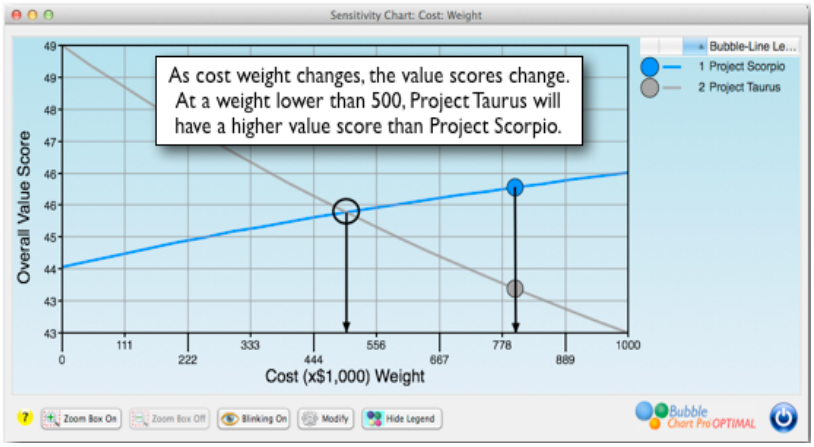

Figure 24 Dynamic Sensitivity Testing (Data, 2011)[226]

Figure 24 is an example of dynamic sensitivity testing, where weight changes are tested on two isolated project scores that have already been ranked. Current location shows the assigned weight of 800 for the criteria "Cost". At present Project Scorpio has a higher overall

[225] Bible, Michael J, Susan Bivins, and Susan S Bivins. 2011. Mastering project portfolio management: a systems approach to achieving strategic objectives. J. Ross Publishing.
[226] Data, Machines. 2011. How to Prioritize Projects. http://www.bubblechartpro.com/content/how_to_prioritize_projects.php.

score than Project Taurus. When weight value is changed to 500 then project score for Project Taurus will be higher than Project Scorpio[227].

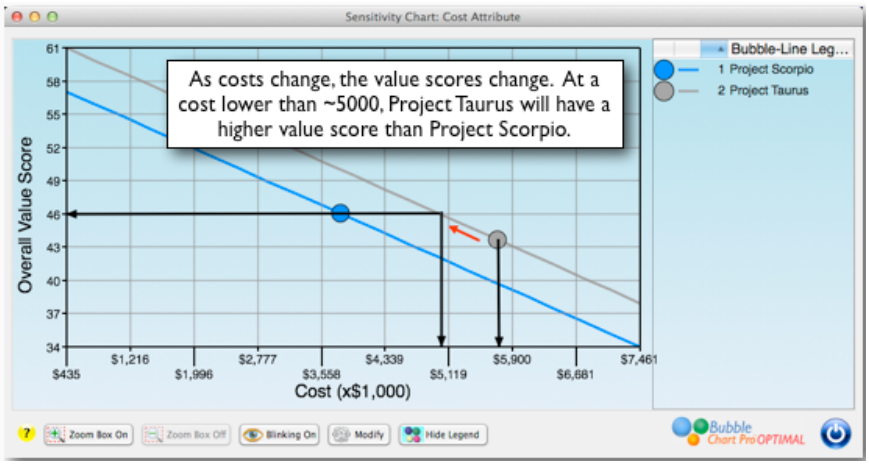

Figure 25 Performance Sensitivity Testing (Data, 2011)[226]

Figure 25 demonstrates performance sensitivity testing where individual criterion changes are tested on two projects overall scores that have already been ranked. The slope of the lines reveals an inverse relationship i.e. as cost go up the project values go down. At present Project Scorpio has a higher overall score. However, at cost of 5,000 or below Project Taurus will achieve a higher over all score than Project Scorpio[228].

[227] Ibid
[228] Ibid

Conclusion

Prioritization of a set of projects from those presented to management is a challenge, as an organization seeks to maximize the effectiveness of its project portfolio. Quantitative mechanisms in evaluating a given project entail reflecting the entire project in terms of the tangible benefits accruable in the future from the initiative. Typically projects are evaluated in terms of a set of criteria, and very often, given the difficulties with quantifying precise values for many or most of these criteria, rating scales are often chosen as a framework for expressing project outcomes. Settlement of the performance measure for every criterion and quantifying relative importance of each criterion over others is challenging and calls for agreement among decision makers. The most intricate part in project evaluation criteria is to find out the mathematical average of every criterion in contemplation of acquiring an overall score used to quantify project performance. In the last step visual models can greatly help i.e. when identifying the optimum project portfolio, the project alternatives are ranked in terms of their strengths such as strategic alignment and then selected due to their limitations such as optimum utilization of finite resources.

The process of prioritizing the various aspects should be ideally considered through a top to bottom approach since as upper management gradually deciphers the organizational strategy and associated business objectives, they go on to perceive the operational aspects required to achieve the same. This calls for close interaction amongst businesses and their technical counterparts towards reconciling their perceptions related to business strategy. Guidelines and references from past work can be utilized for certainty instead of basing all work on guesswork. There will be no difference in the method of making a project proposal regardless of the fact that technology change rapidly in a particular time period. There is the

possibility of new product and process enhancement by examining the past experiences that can further lead to project approval and raising required funds. This is why decision-makers are provided with suitable tools in the decision theory as those help in correct decision making. Nevertheless, it is also pertinent to highlight that there is no single ideal or perfect methodology in this regard. Instead, in consideration of the various players involved, individual stakeholders project their viewpoints as the ideal process to be undertaken. The most significant step is to ascertain good project management downstream no matter what approach is taken on by the company.

In taking corrective actions after mistakes, organizations are liable to ensure that the same are not repeated and in turn bring in marked improvements. The major challenge to resolve is finding a solution to the hindrances faced in the initial attempts. This is achieved in consideration of undertaking the project through passion, hard work, vision, inspiration and a thorough knowledge and understanding of the associated stakeholders, and their political goals. Further, effective portfolio management also requires the consideration of the same principles.

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