MIT | School of Distance Education

A

PROJECT REPORT

ON

"Project Management and its Complexity"

UNDERTAKEN AT

"MIT School of Distance Education"

IN PARTIAL FULFILMENT OF

"PGDM-PROJECT MANAGEMENT"

MIT SCHOOL OF DISTANCE EDUCATION, PUNE.

GUIDED BY "Dr. Jayant Panigrahi"

SUBMITTED BY

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STUDENT REGISTRATION NO.: MIT2022D02066

MIT | School of Distance Education

MIT SCHOOL OF DISTANCE EDUCATION PUNE - 411 038

YEAR 2023-24

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Respected Sir,

This is to request you to kindly exempt me from submitting the certificate for Project Work due to the reason mentioned below:

Tick the right option
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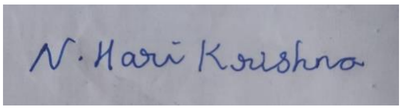
Thanking you in anticipation of your approval to my request.

Regards

Student Sign: - 

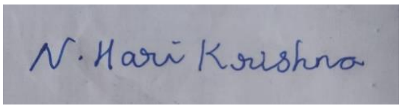
Student Name:- Narava Hari Krishna Kumar

Student ID: MIT2022D02066

DECLARATION

I hereby declare that this project report entitled **"Project Management and Project Complexity"** bonafide record of the project work carried out by me during the academic year **2023-2024**, in fulfillment of the requirements for the award of **"Project Management"** of MIT School of Distance Education.

This work has not been undertaken or submitted elsewhere in connection with any other academic course.

Sign:- 

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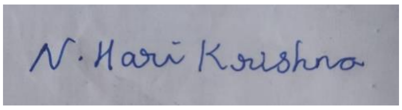
ACKNOWLEDGEMENT

I would like to take this opportunity to express my sincere thanks and gratitude to **"Dr. Jayant Panigrahi"**, Faculty of MIT School of Distance Education, for allowing me to do my project work in your esteemed organization. It has been a great learning and enjoyable experience.

I would like to express my deep sense of gratitude and profound thanks to all staff members of MIT School of Distance Education for their kind support and cooperation which helped me in gaining lots of knowledge and experience to do my project work successfully.

At last but not least, I am thankful to my Family and Friends for their moral support, endurance and encouragement during the course of the project.

Sign:- 

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ABSTRACT

Project management and Project complexity can have a large influence on project execution and project success. In this research, a framework describing project complexity that was developed in the process industry was applied to the semiconductor industry. This framework, called the TOE framework, describes project complexity in these three dimensions: technical, organizational, and external complexities. By performing case studies on a number of projects that are carried out by a semiconductor company, we investigated where complexity comes from in these projects and if it is sufficiently described by the framework.

The outcome of the research is that the framework describes complexity that is found in semiconductor projects reasonably well, although some modifications could be made, such as adding extra complexities to the framework. The next steps after this research project are looking at the practical application of the framework for use in the front-end phase of projects and expanding the research to other companies, to see whether the findings of this research project are generally applicable to the semiconductor industry.

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CHAPTER 1: INTRODUCTION

First let’s understand the project management in detail :

What is Project Management:

Project Management is a process that allows project managers to plan, execute, track and complete projects with the help of a project team. To do so, they must use project management principles, skills, methodologies and tools to lead team members through each of the project management steps which are known as the project lifecycle.

However, project management can’t be defined in one paragraph. In this report, We’ll cover the following topics related to project management:

1) Few basic concepts to understand the project management
2) The stages of the project management process
3) Different types of the project management
4) The tools you can use for managing project

Understanding where complexity comes from in a project is crucial when coping with the complexities that one encounters. Because complexity can have an influence on a project's success, giving sufficient attention to project complexity is important for a company carrying out projects. The main goal of the research project is to understand where complexity comes from in projects in the semiconductor industry and how an existing framework that describes project complexity could be applied to this industry. This paper describes the research that was done in a single semiconductor company on project complexity in the projects that this company executes. The research was done by performing 16 case studies on a selection of projects done within the company.

This article is structured as follows:
1) The article presents the literature concerning project complexity and the semiconductor industry.
2) The research gap that is addressed in this research project is elaborated upon.
3) The methods that were used in the research project are described.
4) The results of the empirical research are presented.
5) The conclusions that are drawn from this research project are shown.
6) The findings of the research project are discussed, and suggestions are given for further research and for the practical implementation of the research findings.

CHAPTER 2: ORGANIZATIONAL PROFILE

MIT School of Distance Education (MITSDE) is an esteemed institution dedicated to providing quality distance education in various fields of study. Established under the flagship of the prestigious MIT Group of Institutions, MITSDE has been at the forefront of delivering industry-relevant education through distance learning programs. With a focus on flexibility, accessibility, and excellence, MITSDE aims to empower learners to achieve their educational and professional goals.

Mission:

The mission of MITSDE is to provide affordable and flexible education through innovative distance learning methodologies. It strives to bridge the gap between academic knowledge and practical skills, enabling students to excel in their chosen fields and contribute to society.

Accreditations and Recognitions:

MITSDE is recognized and accredited by several esteemed organizations, ensuring the quality and credibility of its programs. Some of its accreditations and recognitions include:

- Distance Education Council (DEC): MITSDE is approved by the Distance Education Bureau of the University Grants Commission (UGC) and is a member of DEC.

- All India Council for Technical Education (AICTE): MITSDE is recognized by AICTE, which ensures the quality and standards of its technical programs.

- Association of Indian Universities (AIU): MITSDE is a member of AIU, which validates the equivalence of its programs with traditional degrees.

Programs Offered:

MITSDE offers a diverse range of distance learning programs across various disciplines, catering to the educational needs of working professionals, students, and individuals seeking career advancement. The programs include:

1. Postgraduate Diploma in Management (PGDM): Specializations in areas such as Marketing, Finance, Human Resource, Operations, IT, and Supply Chain Management.

2. Postgraduate Diploma in Business Administration (PGDBA): Specializations in Finance, Marketing, HR, Operations, and IT.

3. Postgraduate Diploma in Infrastructure Management (PGDIM): Focuses on the management of infrastructure projects, construction, and urban development.
4. Postgraduate Diploma in Project Management (PGDPM): Equips students with the skills to effectively manage and execute projects in various industries.

5. Postgraduate Diploma in Retail Management (PGDRM): Focuses on retail operations, merchandising, supply chain management, and customer relationship management.

6. Postgraduate Diploma in Financial Management (PGDFM): Concentrates on financial planning, analysis, investment, and risk management.

Learning Methodology:

MITSDE employs a robust and technology-driven learning methodology to ensure an engaging and interactive educational experience for its students. The key features of its learning approach include:

1. Self-Learning Material: MITSDE provides comprehensive study material in print and digital formats, enabling students to study at their own pace.

2. Online Learning: Leveraging advanced technologies, MITSDE offers online lectures, webinars, e-learning platforms, and interactive sessions to facilitate student-teacher interaction and collaborative learning.

3. Industry-Relevant Curriculum: The curriculum is designed to align with industry requirements and to impart practical skills and knowledge to students, ensuring their readiness for the professional world.

4. Student Support: MITSDE offers dedicated academic support to students through faculty interaction, doubt-solving sessions, online discussion forums, and personalized guidance.

Conclusion:

MIT School of Distance Education (MITSDE) stands as a prominent institution in the field of distance education, committed to providing quality programs and holistic learning experiences to students. With its strong emphasis on flexibility, industry relevance, and student support, MITSDE continues to empower learners, equipping them with the knowledge and skills needed to excel in their careers and contribute to society's growth.

It is contributing to the industrial, economic, and social growth of society for over a quarter of a century, Maharashtra Academy of Engineering Education and Research (MAEER)’s MIT Group of Institutions has helped realize the dreams and aspirations of thousands of students. The group has spread its wings across Maharashtra with campuses in Kothrud, Alandi, and Loni- Kalbhor within Pune, along with Latur, Talegaon, Ambejogai, and Pandharpur.

Being the brainchild of its visionary founder, Prof. Vishwanath D. Karad, MAEER established in 1983, managed to craft a niche position for being a one-of-its-kind undertaking that focused on value-based education.

CHAPTER 3: PROJECT OBJECTIVES AND SCOPE

OBJECTIVE OF STUDY

The objectives of the report on "Project Management & Project Complexity" are as follows:

1) Understand what is project management and it's history.
2) Steps in the project management
3) The article presents the literature concerning project complexity and the semiconductor industry.
4) The methods that were used in the research project are described.
5) The results of the empirical research are presented.

PART A: PROJECT MANAGEMENT

Let's start with the basics of project. Below are the topics that are discussed in the this part a:

1. Definition of project
2. Project characteristics
3. Project life cycle

Project Definition:

Project in general refers to a new endeavour with specific objective and varies so widely that it is very difficult to precisely define it. Some of the commonly quoted definitions are as follows. Project is a temporary endeavour undertaken to create a unique product or service or result.

Project is a unique process, consist of a set of coordinated and controlled activities with start and finish dates, undertaken to achieve an objective confirming to specific requirements, including the constraints of time cost and resource.

Examples of project include Developing a watershed, creating irrigation facility, developing new variety of a crop, developing new breed of an animal, Developing agro processing centre, Construction of farm building, sting of a concentrated feed plant etc. It may be noted that each of these projects differ in composition, type, scope, size and time.

Project Characteristics Despite above diversities, projects share the following common characteristics. Unique in nature. Have definite objectives (goals) to achieve. Requires set of resources. Have a specific time frame for completion with a definite start and finish. Involves risk and uncertainty. Requires cross-functional teams and interdisciplinary approach.

Project Characteristics: Below are the few characteristics that projects share:

1. Unique in nature.
2. Have definite objectives (goals) to achieve.
3. Requires set of resources.
4. Have a specific time frame for completion with a definite start and finish.
5. Involves risk and uncertainty.
6. Requires cross-functional teams and interdisciplinary approach.

Project Life Cycle:

Every project, from conception to completion, passes through various phases of a life cycle synonym to life cycle of living beings. There is no universal consensus on the number of phases in a project cycle. An understanding of the life cycle is important to successful completion of the project as it facilitates to understand the logical sequence of events in the continuum of progress from start to finish.

Typical project consists of four phases- Conceptualization, Planning, execution and termination. Each phase is marked by one or more deliverables such as Concept note, Feasibility report, Implementation Plan, HRD plan, Resource allocation plan, Evaluation report etc.

Conceptualization Phase:

Conception phase, starting with the seed of an idea, it covers identification of the product / service, Pre-feasibility, Feasibility studies and Appraisal and Approval. The project idea is conceptualized with initial considerations of all possible alternatives for achieving the project objectives. As the idea becomes established a proposal is developed setting out rationale, method, estimated costs, benefits and other details for appraisal of the stakeholders. After reaching a broad consensus on the proposal the feasibility dimensions are analysed in detail.

Planning Phase:

In this phase the project structure is planned based on project appraisal and approvals. Detailed plans for activity, finance, and resources are developed and integrated to the quality parameters. In the process major tasks need to be performed in this phase are:

- Identification of activities and their sequencing
- Time frame for execution
- Estimation and budgeting
- Staffing

A Detailed Project Report (DPR) specifying various aspects of the project is finalized to facilitate execution in this phase.

Execution Phase:

This phase of the project witnesses the concentrated activity where the plans are put into operation. Each activity is monitored, controlled and coordinated to achieve project objectives. Important activities in this phase are:

- Communicating with stakeholders
- Reviewing progress
- Monitoring cost and time
- Controlling quality
- Managing changes

Termination Phase:

This phase marks the completion of the project wherein the agreed deliverables are installed and project is put in to operation with arrangements for follow-up and evaluation.

Life Cycle path: The life cycle of a project from start to completion follows either a "S" shaped path or a "J " shaped path (Figure 1 and 2).

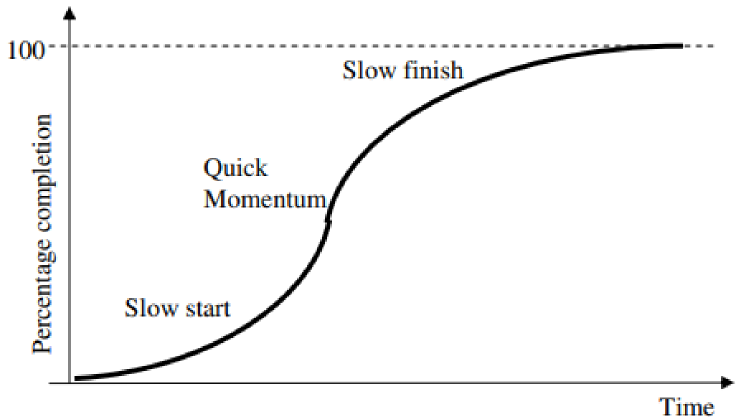

Figure 1. Project life path – "S" shape

In "S" shape path the progress is slow at the starting and terminal phase and is fast in the implementation phase. For example, implementation of watershed project. At the beginning detailed sectoral planning and coordination among various implementing agencies etc. makes progress slow and similarly towards termination, creating institutional arrangement for transfer and maintenance of assets to the stakeholders progresses slowly.

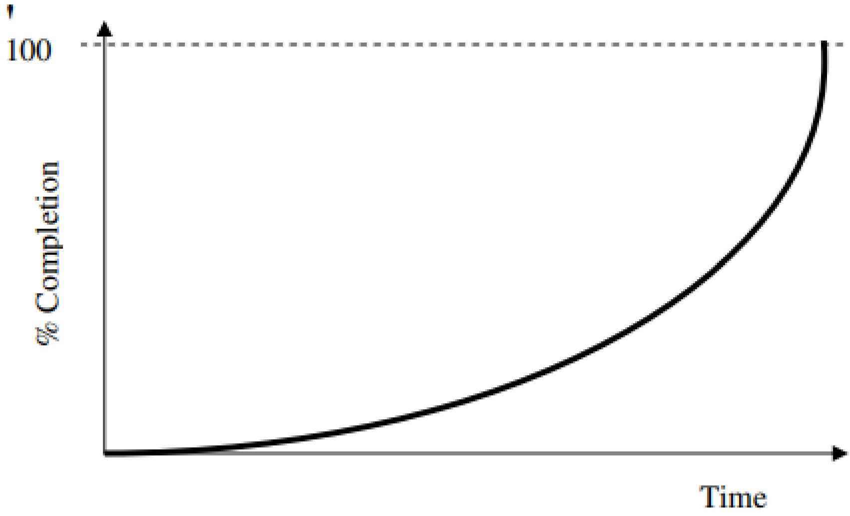

Figure 2. Project life path – "S" shape

In "J" type cycle path the progress in beginning is slow and as the time moves on the progress of the project improves at fast rate. Example, in a developing an energy plantation. In this the land preparation progresses slowly and as soon as the land and seedling are transplantation is under taken. This is shown in above figure 2.

Project Classification:

There is no standard classification of the projects. However considering project goals, these can be classified into two broad groups, industrial and developmental. Each of these groups can be further classified considering nature of work (repetitive, non-repetitive), completion time (long term, shot term etc), cost (large, small, etc.), level of risk (high, low, no-risk), mode of operation (build, build-operate-transfer etc).

Industrial projects also referred as commercial projects, which are undertaken to provide goods or services for meeting the growing needs of the customers and providing attractive returns to the investors/stake holders. Following the background, these projects are further grouped into two categories i.e., demand based and resource / supply based. The demand-based projects are designed to satisfy the customers' felt as well the latent needs such as complex fertilizers, agro-processing infrastructure etc.

The resource/ supply-based projects are those which take advantage of the available resources like land, water, agricultural produce, raw material, minerals and even human resource. Projects triggered by successful R&D are also considered as supply based. Examples of resource-based projects include food product units, metallurgical industries, oil refineries etc. Examples of projects based on human resource (skilled) availability include projects in IT sector, Clinical Research projects in bio services and others.

Development projects are undertaken to facilitate the promotion and acceleration of overall economic development. These projects act as catalysts for economic development providing a cascading effect. Development projects cover sectors like irrigation, agriculture, infrastructure health and education.

Project management:

It is the application of processes, methods, skills, knowledge and experience to achieve specific project objectives according to the project acceptance criteria within agreed parameters. Project management has final deliverables that are constrained to a finite timescale and budget.

A key factor that distinguishes project management from just 'management' is that it has this final deliverable and a finite timespan, unlike management which is an ongoing process. Because of this a project professional needs a wide range of skills; often technical skills, and certainly people management skills and good business awareness.

Project management is aimed at producing an end product that will effect some change for the benefit of the organisation that instigated the project. It is the initiation, planning and control of a range of tasks required to deliver this end product. Projects that require formal management are those that:

- produce something new or altered, tangible or intangible;
- have a finite timespan: a definite start and end.
- are likely to be complex in terms of work or groups involved.
- require the management of change.
- require the management of risks.

Investment in effective project management will have a number of benefits, such as:
- providing a greater likelihood of achieving the desired result.
- ensuring efficient and best value use of resources.
- satisfying the differing needs of the project's stakeholders.

The core component of project management:

- Capturing project requirement, specifying quality of the delivarables, estimating resources and timescales.
- Securing corporate agreement and funding, leading and motivating project delivery team.
- Managing the risks, issues and changes on the project, monitoring progress against plan.
- Closing the project in controlled fashion when appropriate.

Project management is important because it helps organisation control all the moving parts of the project to bring them to successful completion. These moving parts are known as project management areas, which are key project aspects that must be overseen as project progress.

Benefits of Project Management Approach:

• Project management approach will help in handling complex, costly and risky assignments by providing interdisciplinary approach in handling the assignments.

• Project management approaches help in handling assignments in a specified time frame with definite start and completion points.

• Project management approaches provide task orientation to personnel in an Organization in handling assignments.

Project Management History:

Project management as we know it today began taking shape roughly in the 1950s when foundational tools and techniques of project management such as the critical path method (CPM), work breakdown structure (WBS) and the program evaluation and review technique (PERT) were created.

However, the origins of project management can be tracked back to 1986 when Karol Adamiecki created the harmonogram, which was the inspiration for the Gantt chart, which was later created in 1910 by Henry Gantt and remains one of the most important project management tools today. The origins of project management are closely related to construction, engineering, scientific management and even military research.

Steps in Project Management:

The project management process consists of five steps that all projects must go through: initiation, planning, execution, monitoring, control and closure. These project management steps are known as process groups, the project management cycle or the project lifecycle.

1. Project Initiation:

This is the starting period of your project when you should demonstrate the undertaking has value and is feasible. This stage incorporates making a business case, to legitimize the requirement for the undertaking, and an achievable study to show that it very well may be executed within a sensible time and cost. This is likewise an opportunity to make a task contract, a record that sets out precisely the thing the venture will convey.

Documentation: Each project has documentation that should be finished before the undertaking can start vigorously. For instance, there’s a business case, which records the reasons why the undertaking is required and what the profit from speculation will be.

There’s likewise an attainability study to decide whether the undertaking is even conceivable with thought to an association’s assets. The venture sanction gives an overall outline of the task by characterizing the undertaking’s goals, benefits, partners, imperatives, and suspicions, among different angles.

Undertaking a feasibility study: Identify the essential issue your task will tackle and whether your venture will convey an answer for that issue

Recognizing extension: Define the profundity and broadness of the undertaking.

Assemble of the team: You need resources to execute any project. Before you can make a project schedule, you need to create a project team with the skill sets and experience that the project demands.

Recognizing expectations: Define the product or administration to provide.

Recognizing project partners: Figure out whom the venture influences and what their requirements might be.

Building up a business case: Use the above standards to think about the possible expenses and advantages of the task to decide whether it pushes ahead.

Building up an explanation of work: Document the undertaking's goals, extensions, and expectations that you have distinguished already as a working understanding between the venture proprietor and those chipping away at the task.

2. Project Planning:

The second stage is project planning, which happens after the venture has been endorsed. The deliverable of this stage is the undertaking plan, which will be the guide for the execution and control stages. The task plan should incorporate each segment related to the execution of the venture including the expenses, dangers, assets, and timetables. During this stage, the work needed to finish the task, which is known as the undertaking extension, is characterized by utilizing a work breakdown structure (WBS).

The WBS partitions the undertaking into exercises, achievements, and expectations. This permits project chiefs to make plans and dole out errands to their colleagues. Undertaking directors regularly picture their venture plan utilizing a Gantt graph, which addresses the request for errands and how they are reliant. This gives you a guide for the work until the venture arrives at its decision.

Project schedule: The project schedule defines a timeline for the execution of tasks and resource allocation.

Project budget: Undertakings cost cash. They require colleagues to execute different assets, which can incorporate materials, instruments, and so on The financial plan is an approach to appraise the expense of the task.

When you have an arranged spending plan, you can add that to ProjectManager.com and you would then be able to contrast it with the genuine expense of your assets as you execute the venture. That information strings to reports and a constant dashboard, so you're never found napping if costs spike.

Scope management plan: Explains how your project scope will be tracked throughout the project.

Risk management plan: If solitary the venture would adjust to your arrangement. Be that as it may, things occur, and there are consistent changes, some inside your control and others outside it. Before beginning an undertaking you need to attempt to recognize chances and have a danger the board intends to screen and react rapidly to them.

Resource management plan: Describes how your resources will be obtained, allocated and managed during the project. Undertakings are only thoughts until they are given to a colleague to finish. All the readiness you've placed into arranging is subject to getting that task out to the group, so they can do what they were employed to do.

Stakeholder management plan: Identifies all project stakeholders and the guidelines to manage them.

Project managers often lay out their project plan using Gantt chart software, which provides a visual representation of the entire project schedule and project scope. Some Gantt charts automatically identify critical path activities.

3. Project Execution:

The third stage is project execution, which is the place where most of the work occurs. This is the stage where you complete the task exercises and achievements to create the expectations for the customer's or partner's fulfillment by following the arrangement made in the past stage. En route, the undertaking administrator will redistribute assets depending on the situation to keep the group working. They will likewise attempt to recognize and relieve hazards, manage issues, and fuse any changes.

Assignment Management: To ensure an errand is done well, it must be dealt with each progression in transit, from wanting to consummation. This includes observing and answering to ensure the assignment is being executed within the period of the arranged timetable. Venture directors and colleagues need to deal with their undertakings. Assignment records and kanban sheets are two mainstream apparatuses for the task of the board.

Timetable Management: Whenever you've arranged a timetable, you need to screen it through the task execution to ensure it stays on target. A viable Schedule for the executives implies more prominent efficiency. You've to define objectives, needs, and cutoff times, presently as the undertaking errands are being executed, you must ensure those dates are coordinated with your timetable.

Cost Management: Similarly, as you arranged your timetable, you arranged a financial plan. Yet, that doesn't mean your task is finished. As anybody with a wallet knows, cash tends to vanish. You need to control the venture expenses and keep them inside the concurred spending plan.

Quality Management: You can create your expectations on schedule and inside the financial plan, yet if the quality is inadequate, the undertaking isn't effective. In this way, you need to ensure that you're meeting whatever quality prerequisites have been set by your partners.

Change Management: Extensively, changing the board is an interaction for improving business measures, spending designation, and activities in an association. In any case, when applied to protect the board, the center is limited to the actual undertaking and controlling changes in scope during the execution stage.

Acquirement Management: Few is the undertaking that should be possible without buying, leasing, or agreement with outside assets. This interaction is called acquisition. Dealing with the different associations with merchants and providers is what is the issue here.

4. Project task Monitoring and Control:

The fourth project management phase, project monitoring and control, takes place concurrently with the execution phase of the project. It involves monitoring the progress of the project execution activities to ensure the project team stays on schedule and within budget. Quality control procedures are applied to guarantee quality assurance.

Reporting is also a critical part of this project management phase. First, it allows project managers to track progress, and second, it provides data for stakeholders during presentations to keep them in the loop. There are many project management reports such as project status, timesheets, workload, allocation and expense reports.

5. Project Closure:

The fifth stage is project conclusion, in which the last expectations are introduced to the customer or partner. When affirmed, assets are delivered, documentation is finished and everything is approved. Now the venture supervisor and group can lead a posthumous to assess the exercises gained from the project and gain from the experience. Contingent upon the venture, the conclusion stage may likewise incorporate giving over control to an alternate group, for example, the tasks supervisory crew. In this situation, it is the work of the venture supervisor to guarantee that such a change happens easily.

Move Deliverables: Your venture is tied in with creating a deliverable. That denotes the finish of the venture execution and the start of the task close. Subsequently, ensure you have all expectations recognized, total, and given off to the legitimate party.

Affirm Completion: An undertaking isn't over until everybody sings. You need to get affirmation from all partners, customers, and even the group. That implies sign-offs so that there is no disarray and a minute ago change demands.

Those close-down archives can be added to ProjectManager.com, either in the segment of the document or joined to the applicable assignment. Presently you have an advanced paper trail to settle on sure that everybody is in the arrangement.

Audit Documentation: Typically, the venture supervisor is answerable for going over all agreements and documentation to ensure that all have been great and approved. Now and then in bigger associations, there is a devoted administrator for this work. Whoever does it, the significance of ensuring each I is spotted and t crossed couldn't possibly be more significant.

Delivery Resources: Before a task is truly done, you need to authoritatively deliver the group, any contractors, rentals, and so forth Have an interaction set up to advise and ensure everybody is settled up.

Do a Post-Mortem: A posthumous is the point at which you take a gander at the completed undertaking and dissect the cycle to note what worked and what didn't. This is an extraordinary method to rehash triumphs and fix botches for the following undertaking. Likewise, remember to celebrate with your group. They merit it.

Types of project management:

Through the years, many project management methodologies have been developed to adjust to the needs of different industries. Some of these project management types or approaches also work best for projects of certain sizes and complexity levels.

Here's a list of the main project management methodologies. Click the links for an in-depth explanation of each.

1) Agile Project Management

An iterative project management approach that doesn't follow a rigid project plan, but instead short sprints of work called agile sprints.

2) Scrum Project Management

An agile framework that's very popular for product and software development.

3) Lean Project Management (or Lean Manufacturing)

This technique was invented to improve manufacturing processes and became a very important project management methodology through the years.

4) Kanban Method

Kanban is a widely used project management approach that consists of managing work through visual boards and cards. Kanban boards are used by agile and scrum teams.

5) Six Sigma

Just like kanban or lean, six sigma is a set of tools and techniques that were developed to improve production processes and later became a project management approach.

6) Critical Chain Project Management

A project management approach that's based on the theory of constraints and uses resource management as the primary way to execute projects effectively.

Tools / Techniques used for project management:

Project management involves decision making for the planning, organizing, coordination, monitoring and control of a number of interrelated time bound activities. Project Manager therefore, often depends on tools and techniques that are effective enough not only for drawingup the best possible initial plan but also capable of projecting instantaneously the impact of deviations so as to initiate necessary corrective measures. The search for an effective tool has resulted in development of a variety of techniques. These project management techniques can be classified under three broad categories i.e., Project Dashboard, Bar Charts and Networks.

Project Dashboard:

A project dashboard is a project-tracking tool that allows you to monitot your costs, tasks and progress. It's a very useful tool during project execution because it helps project managers quickly determine whether their projects are on track.

BAR Charts:

Bar charts are the pictorial representation of various tasks required to be performed for accomplishment of the project objectives. These charts have formed the basis of development of many other project management techniques.

Gantt Charts:

Henry L Gantt (1861 – 1919) around 1917 developed a system of bar charts for scheduling and reporting progress of a project. These charts latter were known as Gantt Charts. It is a pictorial representation specifying the start and finish time for various tasks to be performed in a project on a horizontal time-scale. Each project is broken down to physically identifiable and controllable units, called the Tasks. These tasks are indicated by means of a bar, preferably at equi-distance in the vertical axis and time is plotted in the horizontal axis (Figure 3).

It is a type of bar chart. A Gantt chart is a visual representation of a project timeline that shows all the project tasks in one graph. Gantt charts are used for project planning, project scheduling, task management and resource management. They work best on waterfall projects.
The Gantt charts is the preferred method used by project managers to schedule their projects. Some tasks are dependent on others before they can start or end, and these task dependencies can create bottlenecks later in the project.

By linking them on the gantt chart, task dependencies help avoid slowing down the schedule. Projects can be divided by milestones and diamond symbols, which indicate the end of one phase and the beginning of the next.

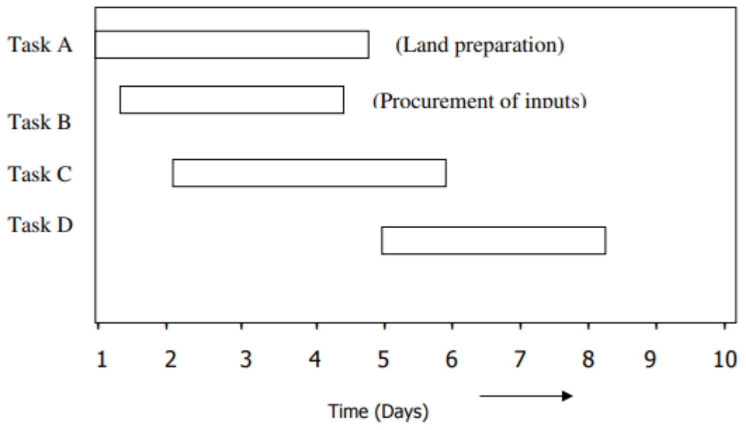

Figure 3: Gantt Chart

Length of the bar indicates required time for the task whereas the width has no significance. Though the bar chart is comprehensive, convenient, and very effective, it has the following limitations:

• Like many other graphical techniques are often difficult to handle large number of tasks in other words a complex project.

• Does not indicate the inter relationship between the tasks i.e., if one activity overruns time what would be the impact on project completion.

Kanban Boards:

A kanban board is a task management tool that allows project managers and team members to visualize tasks. Kanban boards are used by agile and scrum teams who work in iterative sprints. They're easy to use and foster team collaboration.

Milestone Chart:

Milestone chart is an improvement over the bar chart (Gantt chart) by introducing the concept of milestone. The milestone, represented by a circle over a task in the bar chart indicates completion of a specific phase of the task (Figure 4).

In a milestone chart a task is broken down in to specific phases (activities) and after accomplishment of each of the specific activity a milestone is reached or in other words an event occurs. The chart also shows the sequential relationship among the milestones or events within the same task but not the relationship among milestones contained in different tasks.

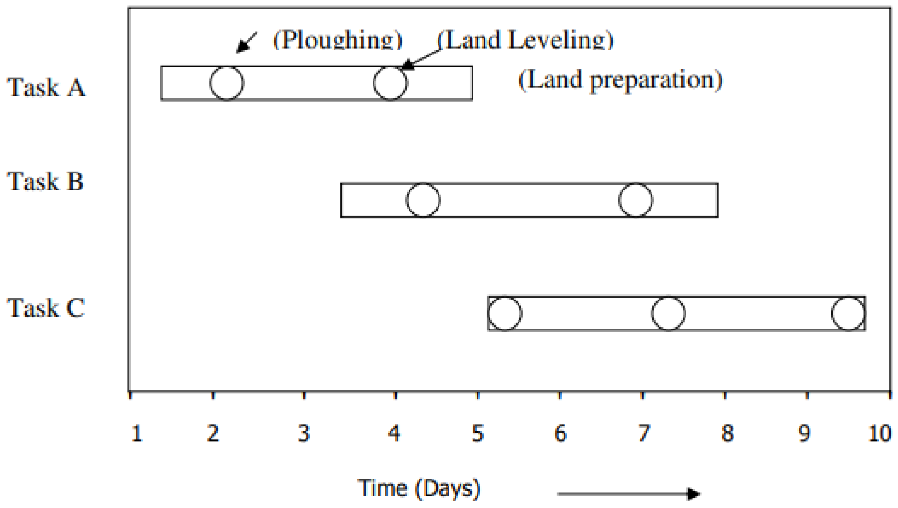

Figure 4: Milestone Chart

The drawbacks of this chart are as follows

- Does not show interdependence between tasks.
- Does not indicate critical activities.
- Does not consider the concept of uncertainty in accomplishing the task.
- Very cumbersome to draw the chart for large projects.

Networks:

The network is a logical extension of Gantt's milestone chart incorporating the modifications so as to illustrate interrelationship between and among all the milestones in an entire project. The two best-known techniques for network analysis are Programme Evaluation and review Technique (PERT) and Critical Path Method (CPM). These two techniques were developed almost simultaneously during 1956-1958.

Though these two methods were developed simultaneously they have striking similarity and the significant difference is that the time estimates for activities is assumed deterministic in CPM and probabilistic in PERT. There is also little distinction in terms of application of these concepts. PERT is used where emphasis is on scheduling and monitoring the project and CPM is used Task where emphasis is on optimizing resource allocation.

PERT:

PERT is also known as Programme Evaluation and Review Technique. e PERT technique is a method of minimizing trouble spots, programme bottlenecks, delays and interruptions by determining critical activities before they occur so that various activities in the project can be coordinated.

The PERT chart is used to schedule, organize and co-ordinate tasks within the project. the objective of PERT chart is to determine the critical path, which comprises critical activities that should be completed on schedule. This chart is prepared with the help of information generated in project planning activities such as estimation of effort, selection of suitable process model for software development and decomposition of tasks into subtasks.

Characteristics of PERT:

The main characteristics of PERT are as following:

1. It forms the basis for all the planning activities.
2. PERT helps management in deciding the best possible resource utilization method.
3. PERT take advantage by using time network analysis technique.
4. PERT presents the structure for reporting information.
5. It specifies the activities that from the critical path.
6. It describes the probability of completion of project before the specified date.
7. It describes the dependencies of one or more tasks on each other.
8. It represents the project in graphical plan form.

Advantages of PERT:

1. Estimation of completion time of project is given by the PERT.
2. It supports the identification of the activities with slack time.
3. The start and dates of the activities of a specific project is determined.
4. It helps project manager in identifying the critical path activities.
5. PERT makes well organized diagram for the representation of large amount of data.

Disadvantages of PERT:

1. The complexity of PERT is more which leads to the problem in implementation.
2. The estimation of activity time are subjective in PERT which is a major disadvantage.
3. Maintenance of PERT is also expensive and complex.

CPM:

Critical Path Method (CPM) is a method used in project planning, generally for project scheduling for the on-time completion of the project. It helps in the determination of the earliest time by which the whole project can be completed. There are two main concepts in this method namely critical task and critical path.

Critical task is the task/activity that can't be delayed otherwise the completion of the entire project will be delayed. It must be completed on time before starting the other dependent tasks.

Critical Path is a sequence of critical tasks/activities and is the largest path in the project network. It gives us the minimum time which is required to complete the entire project. The activities in the critical path are known as critical activities and if these activities are delayed then the completion of the entire project is also delayed.

Benefits of using the critical path method in project management:

1. Show the project schedule visually.
2. Highlight important tasks with CPM.
3. Use CPM to find and handle risks.
4. CPM helps the project team communicate better.

CHAPTER 4: PROJECT COMPLEXITY

PART B: Project Complexity

In the context of projects and project management, a number of authors have reviewed the literature on complexity recognizes different sources of project complexity, namely organizational complexity and technical complexity. In each form of complexity, complexities due to *differentiation* (meaning that complexity comes from the many parts of a system) and due to *interdependency* (meaning that different parts of a system have a certain degree of connection) can be identified. Complexities related to the organization have to do with the organizational structure of a project (i.e., the way the project is organized). Complexities related to technical aspects are, as the name implies, related to the actual contents of the project. Another view on complexity in project management is given by Remington et al.(2009). The authors of this paper identify four dimensions of complexity: *structural, technical, directional*, and *temporal* sources of complexity.

Each of these dimensions has a certain severity in a project, and together they determine the complexity of the project. In the context of the development of complex technical products, a definition was introduced by (Hobday, 1998): Complex Products and Systems (CoPS). Examples of these complex products and systems are technical systems that are developed uniquely (i.e., not in mass production), such as bridges and semiconductor fabrication equipment. Because CoPS often consist of multiple subsystems that need to work together, the architecture of the system plays a large role (Henderson & Clark, 1990). Shenhar and Dvir (1996) and Shenhar (2001) give a typology of engineering projects in two dimensions: system scope (the extent of the system under development; i.e., the place in the hierarchy going from an assembly to an array) and amount of technological uncertainty (from low-tech to super high-tech). This typology is also used by Hobday, Davies, and Prencipe (2005) to extend that framework to the CoPS concept.

Williams (2002) provides a description of complex project management from a systems engineering point-of-view. The use of system dynamics allows the modeler to implement certain characteristics of complex projects into a project model, which can aid in planning the project or in risk management. Cooke-Davies, Cicmil, Crawford, and Richardson (2007) go back to the fact that project management emerged from a Cartesian type of reductionism, but note that there are certain characteristics of complex projects that make this reductionist approach problematic.

There are several (complementary) descriptions of project complexity. Bosch-Rekveldt, Jongkind, Mooi, Bakker, and Verbraeck (2010) give an overview of different definitions of project complexity. In the mentioned article, a third dimension of complexity is added to the complexity framework of Baccarini, namely, complexities that are caused by the environment. These three aspects of complexity (technical, organizational, and environmental) together form the TOE framework (where the acronym stands for the sources of complexity). The TOE framework is described in more detail in the next chapter, where the context of the research problem is investigated further.

The Semiconductor Industry:

The semiconductor industry is a relatively young industry, because active semiconductor devices were discovered relatively recently: the first semiconductor transistor was developed in 1947 at Bell Labs (Jenkins, 2005). Since then, developments have happened so rapidly, that in the modern world, life without semiconductors is almost unimaginable. For an example of the history of the evolution of microprocessors and the markets for these components, see Tredennick (1995).

Semiconductors are — as the name implies — materials that conduct electrical current moderately, but are not completely insulating. By injecting low concentrations of other atomic species (so-called dopants) into certain parts of the semiconductor, the local conductivity of the semiconductor device can be adjusted. In this way, engineers have the possibility to design devices that can perform a multitude of tasks. By integrating several active and passive components in a single device, the integrated circuit (IC) was developed. The best-known semiconductor material is silicon. The word "silicon" is often used as a synonym for semiconductor devices or related technology.

The large-scale production of semiconductor devices became profitable in the 1960s and this allowed for the creation of the semiconductor industry (Walsh, Boylan, McDermott, & Paulson, 2005). Since then, semiconductor devices have exponentially increased in complexity. In 1965, Gordon E. Moore even put this into a law-like form. In this 'law,' Moore stated that the number of components in an integrated semiconductor device double approximately every two years (Moore, 1965). This prediction has held true until this day.

However, not only is the amount of transistors per chip important. For some applications, it is paramount that chips do not fail under any circumstances (for example, the electronics that control the operation of automobiles or medical applications). Other chips need to be able to work under harsh circumstances or have special requirements regarding the amount of power they need to be able to operate in combination with high-frequency operation.

Although semiconductor products are produced in mass production (and therefore cannot be considered CoPS in the strict sense (Hobday, 1998), the development of these products has a number of parallels with the development of CoPS: often, the development of these products is a unique endeavor. In some cases, products are developed that are derivative products of a "platform," but in many other cases, the product under development requires completely new design and architecture. Therefore, the development of new semiconductor products can be quite complex. In fact, complexity and uncertainty (and the ability of companies to cope with these) are directly related to the success of R&D (that is, the processes in which new technologies are developed and applied to create new products) (West, 2000). In another article, West and Iansiti (2003)observe that two processes are responsible for the accumulation of new knowledge in semiconductor industry R&D: experience and experimentation. The processes are subsequently coupled to particular company strategies, which could strengthen each of these processes. West (2000) identifies three processes in the semiconductor industry that give rise to an increase in complexity, uncertainty, and risk: First, the increasing product complexity also leads to increasingly complex production processes. Because more process steps are necessary to produce a product, the chance of failure in one of these steps also goes up, Second, because semiconductor devices often operate near the limits of what is physically possible, it is often unclear what the maximally attainable performance of a semiconductor device is, so this increases the uncertainty about what the possible performance of a device is at the start of the development. Third, increasingly complex production processes require production facilities that are increasingly complex and therefore increasingly expensive. The increased capital costs for these production facilities give rise to an increased investment risk.

Because of a number of properties of the industry, an interesting parallel can be drawn between the semiconductor industry and another industry: the pharmaceutical industry (Lim, 2004). Although these industries produce products that are quite different in nature, there is an important similarity: the costs of research and development are high and the unit production costs are low. On top of this, both basic and applied research plays an important role in R&D activities in both industries.

In the semiconductor industry, project management is applied extensively to developing new products or processes or performing other tasks. Because new technologies are developed rapidly in the semiconductor industry, the execution time of projects is of critical importance. An insight into the complexity of projects would provide valuable knowledge toward the efficient and effective execution of projects.

The Nature and Dimensions of Project Complexity

Complexity in projects isn't limited to a single dimension. It can be technical, relating to the nature of the work or the technologies involved. It can be organizational, involving numerous stakeholders with different interests. It can also be environmental, linked to the project's context, such as regulatory requirements or market conditions. Understanding these dimensions is crucial to managing complexity effectively.

Project complexity is a multifaceted concept that emerges from different project dimensions. These dimensions influence the overall difficulty and intricacy of managing and executing a project. Bewlo are the different types of project complexities:

Technical Complexity:

Technical complexity pe rtains to the technological and operational aspects of a project. This could include the technologies used, the nature of the tasks performed, or the processes involved.

For example, a project involving a new software product with an unproven technology stack would have high technical complexity. Similarly, a manufacturing project with intricate production processes would also be technically complex.

Organizational Complexity:

Organizational complexity refers to the complexity arising from the project's organizational environment. This includes the number and diversity of stakeholders, the organizational structure, and the culture and politics within and around the project.

For instance, a project involving multiple teams from different departments or companies, each with its interests and ways of working, would have high organizational complexity.

Environmental Complexity:

Environmental complexity encompasses the external factors that influence the project. These could include regulatory requirements, market conditions, social or cultural factors, or environmental conditions.

For example, a project that involves constructing a building in a highly regulated area or a volatile market would have a high degree of environmental complexity. Similarly, a product development project for a culturally diverse market could also be environmentally complex.

Temporal Complexity:

Temporal complexity relates to the timing and scheduling aspects of the project. This includes the project's duration, the sequencing of tasks, and the interdependencies between tasks.

For example, a project with tight deadlines, numerous interdependent tasks, or a need for precise sequencing would have a high degree of temporal complexity.

Ambiguity Complexity:

Ambiguity complexity involves the degree of uncertainty or ambiguity in the project. This could be due to unclear project objectives, undefined roles or responsibilities, or unpredictability in the project's requirements or outcomes.

For example, a project with unclear objectives, undefined roles or responsibilities, or unpredictable outcomes would have high ambiguity and complexity.

Each of these dimensions adds a layer of complexity to a project, and they often interact with each other in complex ways. Understanding these dimensions is crucial for managing project complexity effectively.

Challenges Presented by Complex Projects:

Complex projects present numerous challenges. They often have high levels of uncertainty and risk, are subject to frequent changes, and require significant coordination and communication. They also tend to demand a high level of expertise and specialized skills.

Complex projects, by their very nature, present a host of challenges that can be difficult to navigate. These challenges can vary depending on the project's specific characteristics, but several common themes tend to emerge.

Increased Uncertainty and Risk:

One of the most significant challenges of complex projects is the increased uncertainty and risk. Due to the multiple interconnected elements, any change or issue in one area can ripple throughout the project, leading to unforeseen problems. This uncertainty can make it difficult to plan accurately and requires a flexible and responsive approach to project management.

Coordinating Multiple Stakeholders:

Complex projects typically involve numerous stakeholders with needs, expectations, and interests. Coordinating among all these stakeholders and ensuring effective communication can be a significant challenge. Managing conflicting interests and keeping all stakeholders aligned and committed to the project objectives can be especially difficult.

Managing Complex Interdependencies:

In complex projects, tasks and components are often highly interdependent. One task's output can significantly impact others' inputs and outcomes. Managing these interdependencies requires a deep understanding of the project's components and a strategic approach to scheduling and coordination.

Ensuring Effective Communication:

The complexity of a project can make effective communication more challenging but also more critical. Misunderstandings or lack of information can lead to errors, conflicts, and delays. Ensuring that all team members and stakeholders have the information they need when needed can be challenging but crucial.

Adapting to Changes:

Complex projects are often subject to frequent and significant changes. These can stem from external factors, such as changes in market conditions or regulatory requirements, or internal factors, like changes in project objectives or team composition. Adapting to these changes while keeping the project on track can be challenging.

Developing and Maintaining Expertise:

Complex projects often require a high level of expertise and specialized skills. Developing and maintaining this expertise within the project team can be a significant challenge, particularly for projects that involve novel or rapidly evolving technologies.

Balancing Efficiency and Flexibility:

Finally, one of the overarching challenges in managing complex projects is finding the right balance between efficiency and flexibility. While efficiency is essential for meeting project deadlines and budgets, flexibility is crucial for adapting to changes and managing uncertainties. Striking the right balance can be a challenging but essential task.

Identifying Signs of Complexity in Your Project:

Specific indicators often signal complexity. These can include many stakeholders, frequent changes in project scope, high levels of uncertainty or ambiguity, extensive interdependencies between tasks, and the need for novel or unproven technologies.

Recognizing the signs of complexity in a project is vital to implementing effective management strategies. Here are several signs that a project may be complex:

Multiple Interconnected Tasks:

One sign of a complex project is the presence of numerous interconnected tasks. If a project requires a large number of tasks to be performed, and the output of one task significantly influences the inputs and results of others, this is a clear sign of complexity.

Numerous Stakeholders:

Complex projects often involve a large number of stakeholders. These could include clients, team members, suppliers, end-users, and regulatory bodies. Each stakeholder may have unique expectations and requirements, and managing all these different needs can add significant complexity to the project.

High Level of Uncertainty:

A high level of uncertainty is another sign of project complexity. This could be due to unpredictable external factors, such as market conditions or regulatory changes, or internal factors, such as unproven technology or unclear project objectives.

Frequent Changes:

If a project is subject to frequent changes in scope, objectives, team composition, or other factors, this can be a sign of complexity. Such changes can disrupt plans, increase uncertainty, and challenge project management.

Specialized Knowledge or Skills Required:

This can increase its complexity if a project requires specialized knowledge or skills related to technology, industry regulations, or other factors. The need for specialized knowledge can make it harder to find suitable team members and increase the risk of errors or oversights.

Innovative or Unproven Technology:

Projects that involve the use of innovative or unproven technology can be particularly complex. The potential for unknown issues, the need for specialized knowledge, and the likelihood of changes and adjustments can all add to the complexity.

Large Scale or Long Duration:

Finally, the scale or duration of a project can contribute to its complexity. Large-scale projects often involve more tasks, stakeholders, and resources, increasing the complexity. Similarly, long-term projects are more likely to be affected by changes and uncertainties, making them more complex to manage.

Identifying these signs early can help project managers to implement appropriate strategies and tools to manage the complexity effectively.

The Impact of Complexity on Project Management:

Complexity can significantly affect project management. It can increase the time and resources needed to complete the project, raise the likelihood of errors or oversights, and make it more difficult to predict outcomes. It can also place additional stress on the project team, potentially leading to conflicts or misunderstandings.

Project complexity significantly impacts project management, from planning and execution to monitoring and controlling. Here are some ways complexity can affect project management:

Planning Challenges:

Complex projects often pose significant challenges during the planning phase. The interdependencies among tasks can make creating a realistic and practical project plan complex. Additionally, the high levels of uncertainty and ambiguity can make it hard to predict the resources required, the time needed for each task, and the potential risks.

Increased Resource Requirements:

Complex projects generally require more resources than simpler ones. This includes the financial resources needed to execute the project and the human resources needed to manage it. Complex projects often require a larger team with diverse skills and expertise.

Risk Management:

Complex projects tend to carry more risks due to their inherent uncertainty, the large number of stakeholders, and the high degree of interdependence among tasks. These risks can impact various aspects of the project, from the schedule and budget to the quality of the outputs and the stakeholders' satisfaction.

Stakeholder Management:

The many stakeholders involved in complex projects add another complexity regarding communication and expectation management. Ensuring all stakeholders are informed and their needs and expectations are met is a significant challenge in complex projects.

Need for Flexibility:

Due to their inherent uncertainty and the high likelihood of change, complex projects require a high degree of flexibility. This means that project managers must be prepared to adapt the project plan, objectives, and strategies as the project evolves.

Quality Control:

Maintaining the quality of outputs in a complex project can be challenging. The high degree of interdependence among tasks means that an issue in one area can affect the quality of the overall project. This requires robust quality control processes and a proactive approach to problem-solving.

Increased Need for Communication:

Complex projects require effective communication to ensure all team members and stakeholders are aligned and informed. This can involve significant time and effort, especially in projects with large teams or numerous stakeholders.

In the end, complexity significantly impacts project management, necessitating more strategic planning, robust risk management, effective stakeholder management, and strong communication skills. However, with the right strategies and tools, these challenges can be successfully navigated, turning complexity from a challenge into an opportunity for learning and innovation.

Conclusion: Turning Complexity into an Advantage

Project managers can navigate complexity effectively and unlock its potential for innovation, growth, and competitive advantage by adopting the right strategies, tools, and mindset. Here are key points to consider when aiming to turn complexity into an advantage:

Embrace Complexity:

Rather than viewing complexity as a hindrance, organizations should embrace it as an opportunity for learning, adaptation, and growth. Recognize that complexity is inherent in today's dynamic business environment and be willing to explore new approaches to managing complex projects.

Develop a Complexity Mindset:

Cultivate a mindset that acknowledges and understands complexity. Encourage project teams to think holistically, consider interdependencies, and embrace flexibility in response to evolving circumstances. Foster a culture that values continuous learning and improvement in navigating complexity.

Effective Leadership and Team Collaboration:

Strong leadership is crucial in managing complex projects. Leaders should inspire and empower their teams, foster collaboration, and create an environment encouraging open communication and knowledge sharing. Leverage the diverse expertise and perspectives of team members to tackle complex challenges.

Adopt Agile and Iterative Approaches:

Agile methodologies, such as Scrum and Kanban, can effectively manage complex projects. These approaches promote flexibility, adaptability, and continuous improvement.

Break down complex projects into smaller, manageable iterations, allowing for faster feedback, course correction, and early value delivery.

Utilize Technology and Project Management Tools:

Leverage technology and project management tools to streamline communication, collaboration, and project control. Project management software, communication platforms, and data analytics tools can provide valuable insights, enhance team productivity, and facilitate effective decision-making in complex project environments.

Invest in Training and Development:

Recognize that successfully managing complex projects requires continuous professional development. Invest in training programs and mentorship opportunities to equip project managers and team members with the necessary skills, knowledge, and competencies to navigate complexity effectively.

Learn from Experience:

Capture and apply lessons learned from previous complex projects. Develop a culture of knowledge sharing and continuous improvement, ensuring valuable insights are integrated into future project planning and execution. Regularly evaluate project performance, identify areas for improvement, and implement corrective actions.

Collaborate with Stakeholders:

Engage stakeholders early and throughout the project lifecycle. Foster strong relationships, manage expectations, and ensure effective communication. Collaboration and stakeholder engagement can help identify potential complexities, mitigate risks, and align project objectives with broader organizational goals.

Focus on Innovation and Adaptation:

View complexity as an opportunity for innovation and creativity. Encourage the exploration of new ideas, alternative approaches, and emerging technologies. Foster an environment that encourages experimentation, learning from failures, and continuous adaptation to stay ahead in complex project environments.

Organizations can transform complexity from a potential barrier into a catalyst for success by adopting these strategies. With the right approach, organizations can thrive in complex project environments and achieve successful project outcomes that drive their overall success.

CHAPTER 5: TOE FRAMEWORK

As was mentioned before, the TOE framework aims to understand the different aspects of project complexity. This framework was developed on the basis of empirical research in the process industry. In the appendix, an overview is given of the TOE framework as it is described in (Bosch-Rekveldt, 2011; Bosch-Rekveldt, Jongkind, et al., 2010). The TOE framework serves as the basis of this research project. The TOE framework consists of 47 elements; each describes a single aspect of complexity that can occur in a project.

The elements are divided into three categories of complexities: technical (17 elements), organizational (16 elements), and external (14 elements). What these complexities actually entail can be seen in the appendix to this article. Technical complexities are related to the technical content of a project, such as goals, scope, tasks, experience, and technical risk; organizational complexities are related to the organizational aspects of a project, such as resources, the project team, trust, and organizational risk; external complexities are complexities that are related the environment in which the project is executed, such as stakeholders, location, market conditions, and external risks.

One of the goals of this research project is to see whether the existing TOE framework would fit the current practice at a semiconductor company. The outcome of the research should then give indications of the types of complexities that semiconductor companies encounter in their projects.

Methods:

The empirical part of this research project consisted of 16 qualitative case studies of projects that are carried out at the semiconductor company. For each case study, we chose as the research strategy to do the empirical part of the research, because our goal was to study a contemporary real-life situation (Yin, 2003). We chose the amount of 16 cases to get a good balance between a broad overview of project that is executed in the company and the time that was available to execute the research. On top of this, the choice was made to perform one interview per case, to be able to consider a large amount of different cases. Because the interviewee had to have the most extensive knowledge about the project, the project manager was interviewed, who was involved in all of the different aspects of the project. A downside to this approach is that the researcher only gets a single perspective on the case.

The projects that were studied in this research project differed in a number of ways. Two main types of projects under study can be distinguished in this research project: product development projects and process development projects. Furthermore, projects from different functional areas within the company were studied (these functional areas differ in the types of applications for which products are developed). From the 16 investigated projects, some were finished, some were unfinished (albeit in an advanced stage), and some were terminated.

LIMITATIONS:

The approach taken has a number of limitations: Because a limited number of cases have been studied in this research project, one could ask the question whether this number of cases is sufficient to draw general conclusions from the data gathered. We tried to make this limitation as small as possible by carefully choosing a set of projects that covers a broad number of subjects in which the company is active. To ensure construct validity and reliability of the findings, all interviews have been recorded and the worked out interviews were sent back to the interviewees for review (reference check method). This way, we could make sure that what we wrote down was what the interviewee was thought to have said.

RESULTS:

In this section, the results and analyses of the empirical part of this research project are presented:

First, we will cover the backgrounds of the interviewees who were parts of this research project.

Interviewee Background:

All project managers who were interviewed in this research project had a technical background: they all started in an engineering role (project team member) before obtaining the role of project manager. Out of the 16 interviewees, 12 interviewees had a background in electrical engineering or related field, 3 interviewees had a background in physics, and 1 interviewee had a chemical engineering degree. This observation could have profound implications for a possible application of the framework at the company to assess project complexity, such as the particular way of implementation of the framework (e.g., types of questions that are asked in a complexity assessment).

Second, we will shortly discuss the different project types that we encountered during the research.

Project Types Encountered:

In general, a distinction can be made between two types of projects in this research project: product development projects and process development projects. In a product development project, the main goal is to develop a new product (this can be the development of a completely new conceptual product or the further development of an existing product). Because the fabrication process of semiconductor devices consists of many steps, the processes that make up this fabrication process are continuously being improved. The process improvements or developments are often done in the form of a process development project.

Concerning the product development projects that were studied, we can make a number of interesting observations. An important factor in the development of new semiconductor products is the type of design effort that is necessary to create such a product: the nature of the design can either be digital (where the signals that the device processes are zeros and ones), analogue (where the signals that the device processes are continuous; i.e., these signals can take on a range of different values), or mixed-signal (in this case, digital and analogue signals are both processed on the device). In general, digital products are easier to design and model than analogue products. Each type of design asks for a different approach and for different areas of expertise to be present in the design team.

Although the chip design is an important step in the development process, it is certainly not the only step that is taken to deliver a successful product. Because each device needs to be tested after it is manufactured, test engineers develop industrial tests to determine that each chip works. Developing these specialized tests for each new device is a part of the development project. Also, an industrial mass-manufacturing method needs to be developed to produce the chips at the lowest possible unit cost. The attentive reader might note that the different expertise areas that are involved in the project might also have conflicting interests. It is therefore the challenge to the project manager to bring these together. One interesting aspect of project complexity that came forward from the interviews is the availability of simulation models to correctly predict the behaviour of the product under operating conditions. On one hand, the manufacturing of prototype models is an expensive exercise, so simulating the behaviour of a device would save costs. On the other hand, the right simulation models are not always present, because a device can operate in a parameter regime that is not covered by existing models. The absence of the right models is therefore a source of complexity in semiconductor projects where devices are developed that work in new regimes. This aspect of complexity is also described in general by the TOE framework.

Third, the different drivers behind the projects are discussed.

Project Drivers:

During the interviews, the project managers were asked to rank the project drivers (project cost, schedule, and specifications) in order of importance with respect to the project under study, where 1 is most important and 3 is least important. The outcome of this measurement is shown in below Table 1.

Table 1: An overview of the average ranks and standard deviations of project drivers in the interviews.

N = 16	Specifications	Schedule	Project Cost
Average rank	1.375	1.675	3
Standard deviation	0.5	0.5	0

Fourth, an overview is given of the complexities that were mentioned by the interviewees before they were introduced to the framework.

Fifth, the scores of the elements in the TOE complexity framework are presented.

TOE Scores:

After an introduction to project complexity, where the interviewees were asked about their perception of project complexity, the interviewees were confronted with the existing TOE framework. This resulted in 16 filled-out versions of the TOE framework, in which the applicability of each element to the respective projects was indicated (1 to 5; the higher, the more applicable). In the appendix, an overview is given of the scores of the different elements in the case studies. In this section, we will highlight three different results: high scoring elements, low scoring elements, and elements that had a high number of "not applicable" scores given.

The elements that had high scores (scoring 4.00 or more on average) were (in parentheses, the element code, mean score, and standard deviation are given):

- High project schedule drive (ORE1, 4,44 (0.63))
- Level of competition (EM3 4.07 (0.59))
- Involvement of different technical disciplines (TT5, 4.06 (0.68))
- Technical risks (TR1, 4.00 (1.15))

These elements reflect the challenges with which the project teams have to cope: the teams need to consist of team members of different backgrounds (which can introduce communication problems); the products that are developed are often very innovative, which means that a certain amount of uncertainty exists about whether the developed product can live up to the needed specifications; there is a large amount of pressure from competitors, which means that new products need to be developed fast.

The elements that had low scores (scoring 1.50 or less on average) were (between parentheses, the element code, mean score, and standard deviation are given):

- Number of financial source (ORE6, 1.17 (0.58))
- Trust in the project team (OT1, 1.50 (0.97))
- Trust in contractor (OT2, 1.22 (0.44))

One has to take notice that the fact that these elements scored low values does not mean that these elements are unimportant: it might very well be that these elements scored low scores, because the company took sufficient measures to control the influence that these elements have on the different aspects of complexity of the projects. A number of elements had higher "not applicable scores than other elements". The following elements had "not applicable" scores of more than 75%"

- Lack of HSSE awareness (ORE4, 75% NA)
- Presence of JV (joint venture) partner (OP3, 88% NA)
- Political Influence (ES4, 81% NA)
- Required local content (ES6, 81% NA)
- Remotness of location (EL3, 81% NA)

From these elements, one element deserves special attention: Presence of a JV partner (OP3). Although this element was deemed to be not applicable in 14 out of the 16 cases, there was a joint venture partner present in two projects, and the presence of the JV partner in these projects did contribute toward the total complexity of the project. Hence, the presence of a JV partner is still an important element that possibly can have an influence on the (organizational) complexity of a project.

Finally, the elements that were lacking in the original framework according to the interviewees are listed:

Missing Elements:

Before the interviewees were introduced to the TOE framework, they were asked if they could mention a number of complexities that could be present in projects in the semiconductor industry. In addition, to see whether the framework sufficiently describes the complexity of projects at the company, interviewees were asked to mention complexities they encountered in their experience in projects, but that the framework did not (sufficiently) describe. Below, we will give an overview of the extra elements that were mentioned at least by three different project managers (independently from each other, before or after the interviewees were introduced to the framework):

- New combination of technologies
- Multiple companies/ departments in a single team
- New market
- The availability of modelling tools.

The TOE Framework in Future Research:

To this point, the majority of the theoretical development that has taken place related to the TOE framework has been limited to enumerating the different factors that are relevant in various adoption contexts. No new constructs have been added to the framework. Little theoretical synthesis has occurred. Scant critique has been offered. Thus, the TOE framework has evolved very little since its original development. In this section, reasons for this lack of theoretical development will be presented, followed by directions for future research.

Reasons for Lack of Development:

There may be multiple reasons for the relative lack of evolution and change in the TOE framework since its initial development. First, the TOE framework has been described as a "generic" theory. This assessment seems appropriate considering that the theory has come to be used as a framework within which a host of various factors can be placed. The freedom to vary the factors or measures for each new research context makes the TOE framework highly adaptable. Thus, scholars have seen little need to adjust or refine the theory itself.

Second, the TOE framework may have seen relatively little evolution because it has been viewed as aligned with other explanations of innovation adoption – rather than offering a competing explanation to them. Tension between the TOE framework and other theories has been seen as slight, and this tension has, at this point, to be resolved by allowing the TOE framework to subsume competing ideas, rather than respond to them. For instance, it has been noted that the TOE framework is consistent with the theory of the diffusion of innovations. The DOI adoption predictors, individual leader characteristics and internal characteristics of organizational structure are said to be comparable to the TOE's organizational context element.

Future Directions for TOE Research:

Future research with the TOE framework can take a number of directions. Perhaps the most obvious is that the TOE framework can continue to be used for empirical research. As long as new technologies are developed, and as long as novel contexts for adoption can be identified, the need to understand the adoption of innovation in organizations indicates that the TOE framework is capable of providing insights for researchers and practitioners. Thus, continued empirical work is one future direction for TOE research. Other possibilities exist as well. For instance, one area of interest to researchers is interorganizational adoption.

The TOE framework has been used to study the adoption of interorganizational systems, but only from the perspective of a single focal firm. Extant research does not examine how decisions are made when multiple firms must collectively reach a decision about a new system. How do the multiple firms' multiple technological contexts influence adoption? How do the multiple firms' multiple organizational contexts influence adoption? Is the environmental context viewed differently by different firms? Does the position of a firm in the value chain cause it to view new technologies differently than its value chain partners view those same technologies?

Exploration and investigation of each of these questions would allow researchers to extend the TOE framework in ways that would increase its explanatory power or possibly reveal its limits. Such research would also provide actionable insights for practitioners in an age of increasing organizational interconnections.

Additionally, theoretical synthesis may extend and enrich the TOE frame-work. For instance, one explanation for the organizational adoption of many types of technology – an explanation that has slightly different emphases than the TOE framework is that of network externalities. When the value of an innovation depends on the number of other users or other firms who adopt that innovation, positive adoption externalities, also known as network effects or network externalities, are said to exist (Katz and Shapiro 1985, 1986).

Network effects can be either direct network effects, which are the physical effects of being able to exchange information, or indirect network effects, which arise from the interdependencies with other organizations in the use of complementary goods (Katz and Shapiro 1985, 1986; Weitzel et al. 2006).

In developing the TOE framework, it was decided to maintain the richness of elements contributing to project complexity as found in literature and practice and not to reduce to a 2 × 2 matrix, as suggested amongst others in recent research of Whitty and Maylor (2009) on the structural Dynamic Interaction matrix. The broad TOE framework with its three levels (categories, subcategories and elements) offers the opportunity to discuss on various levels of aggregation with the different parties and stakeholders involved in a project which aspects make the specific project complex, in their individual views.

The current setup also allows extension of the framework for use in different industries. The framework thus developed can be used to assess the complexity of an engineering project. Assessing a project's complexity is a subjective process by nature, in which perceived complexity based on previous experiences plays an important role. Because of the differences in skills and experiences, people using the framework and assessing a certain project or phase thereof may come to different conclusions regarding its complexity.

The objective of the framework at this stage, however, is primarily to achieve a better understanding of project complexity and get a footprint of the project's complexity. Regardless of absolute scores for the different elements, this framework enables identification of the complexity areas in a specific project. Knowing these complexity areas, attention could be paid to the management of these. And as stated by Geraldi (2009, p.665): the "assessment of complexity itself is a tool to enable such active management".

Conclusion of project complexity:

T o help manage project complexity, this paper presented a framework for characterising project complexity in large engineering projects. The TOE framework is based on both literature and empirical data. Applying the framework for a specific project results in a footprint of its complexity, providing potential handles to better manage the project. The framework is intended to be used for assessment of complexity of projects in the process engineering industry. Because of the dynamics of project complexity, repeated use in different project phases is foreseen.

Using an inductive approach by combining literature insights strengthened with the elements results, the TOE framework enables abroad view on project complexity. In total 50 elements contributing to project complexity were identified in the following three areas: technical complexity, organizational complexity and environmental complexity. Deliberately, the number of elements in the framework was not reduced to be able to describe the richness of project complexity.

To facilitate its use, three levels were defined within the TOE framework; three categories (TOE), fourteen subcategories (goals, scope, tasks, experience, and risk; size, resources, project team, trust, and risk; stakeholders, location, market conditions and risk) and fifty elements. This offers the opportunity to discussion various levels with the different parties and stakeholders involved in a project which aspects make the specific project complex. The current setup is flexible and allows extension of the framework, for example if necessary for use in a different industry.

The resulting TOE framework was reflected against current literature concepts and was shown to integrate the current dominant concepts. Moreover, the concepts were developed into clear elements in the TOE framework bringing together theoretical perspectives and perspectives from practice.

To overcome current research limitations, completeness of the framework and repeatability and reproducibility of using the framework will be investigated by means of a quantitative approach. For this, an internet survey is performed to investigate project complexity in a country specific, industry wide, competence network, including owner as well as contractor perspectives. Once the complexity of a project is better understood, it will be investigated as how to better fit the front–end phase of projects to the particular types of project complexity in order to improve the project performance. Part of this fitting could be mapping the project manager's competences to the particular project complexity using the TOE framework.

CHAPTER 6: DATA COLLECTION

DATA COLLECTION:

Interviews of approximately 60 minutes were held with the interviewees. To ensure data reliability, the interviews were recorded, next to the notes that were taken during the interview. A worked out version of the interview was sent back to the interviewee to ensure that the right information came across. During the interviews, the interviewees were asked about the content of the project under study and about their views on project complexity (i.e., project complexity in the semiconductor industry in general, not limited to the single project that was treated in the interview). Subsequently, the interviewees were introduced to the TOE framework and were asked to fill in a scoring chart of the TOE framework, related to the project under study.

The interviewees were asked to give a score to each complexity in the framework, related to the applicable of that complexity to the project. The scores ranked from 1 (least applicable) to 5 (most applicable). If a complexity was completely non-applicable to the project, the interviewee could also give an NA (not applicable) mark. After filling out the framework, the interviewees were asked if they missed any complexities in the framework, and if this was the case, which complexities could be added to improve the framework.

DISCUSSION:

Obviously, the results are very much dependent on the selected project sample for the case studies. The case studies resulted in a number of elements that were most prominent in the 16 investigated cases. Apart from the element *high schedule drive*, the highest scoring elements were less prominent in the studies performed in the process industry (Bosch-Rekveldt, 2011). The lowest scoring elements and those indicated with “not applicable” are not that surprising; just compare the context of typical semiconductor industry projects with the context of typical process industry projects. The missing elements, according to the interviewees, then make us pose the question of whether or not to include these in a next version of the TOE complexity framework. At this stage, however, we would only recommend to add these elements for particular use in the semiconductor industry.

CHAPTER 7: CONCLUSION

CONCLUSION

During the interviews, we have seen that the projects are almost always executed in multidisciplinary teams. The reason for this is the wide variety of expertise areas that are necessary to develop a new product or process in the semiconductor industry. Moreover, teams are often dispersed over different locations, sometimes even over different continents. This dispersion has profound implications on the way different team members can communicate with each other. Because there is constant market pressure on the company, the company needs to develop innovative product constantly. This research project showed that the main drivers behind the project are the specifications of the project and the schedule. A good support structure from within the company is needed to be able to efficiently and effectively develop new products and processes, which we have seen in the case studies.

If one looks at the different complexities that play a role in the projects that were studied, one could say that, in general, technical complexities play a relatively large role. In particular, the technical complexity of the product that is being developed in a project (e.g., the ability to model the behavior of a product under development before a test product is made) and the influence of the market on the project play a large role in the complexity of the project.

We have seen that not all elements that are parts of the TOE framework are equally important to the current practice in the semiconductor company. On the whole, however, the framework seems to describe complexities that are encountered in the projects quite well.

FURTHER RESEARCH:

Although preliminary conclusions can be drawn from the TOE scores, these scores were still obtained from a relatively small number of cases; therefore, one has to be very careful drawing general conclusions from these outcomes.

The case studies that have been performed have yielded results about the ways in which complexities influenced these cases and to which degree each complexity had an influence on the projects. Because 16 projects have been investigated in this research project, more research could also be done on more cases within other companies. This would allow the researcher to see if the results that were found in this research project are also more generally applicable. A second strategy used to test the validity of the framework to semiconductor projects would be to set up a survey, whereby a larger number of projects could be investigated.

Applying the framework in the front-end phase of a semiconductor project could provide benefits to the company. In the case studies and in the literature, we have seen that complexities can have a large influence on the project's execution and success. A tool that could assess the complexity and sources of complexity of a project would be valuable to a company. Certain tools that do this already exist, but these are mainly concentrated on the design complexity of a new product. The framework that we have used in this research project would be applicable to a larger class of (development) projects. For further application of the framework in practice, the amount of effort that would be needed from the project manager to fill in the framework would need to be assessed.

The main benefit of the use of the framework would probably be the estimation of the types of complexities that are encountered during a project. Of course, it is also important to assess whether the extra effort that is needed from the project manager and project team pays off against the possible gains of using a complexity framework. It would also be interesting to look at the dynamics of project complexity: how project complexity and the perception of project complexity change during the course of a project. As was brought forward in the literature study, interesting parallels can be drawn between the semiconductor industry and the pharmaceutical industry; therefore, it would be very interesting to perform the same research exercise in that industry as well. This way, one could see whether parallels can also be found in project complexities that are encountered in this industry.

CHAPTER 8: APPENDIX

Appendix: Elements of the TOE Framework

Technical Elements:

Sub-ordering	Element code	Element
Goals	TG1	Number of project goals
Goals	TG2	Non-alignment of project goals
Goals	TG3	Un-clarity of project goals
Scope	TS1	Uncertainties in scope
Scope	TS2	Strict quality requirements
Scope	TS3	Project duration
Scope	TS4	Size in CAPEX (Capital Expenditure)
Scope	TS5	Number of locations
Experience	TE1	Newness of technology (worldwide)
Experience	TE2	Experience with technology
Tasks	TT1	Number of tasks
Tasks	TT2	Variety of tasks
Tasks	TT3	Dependencies between tasks
Tasks	TT4	Uncertainty in methods
Tasks	TT5	Involvement of technical disciplines
Tasks	TT6	Conflicting norms and standards
Risk	TR1	Technical risks

Organisational Elements:

Sub-ordering	Element code	Element
Resources	ORE1	High project schedule drive
Resources	ORE2	Lack of resource and skills availability
Resources	ORE3	Lack of experience with parties involved
Resources	ORE4	Lack of HSSE awareness
Resources	ORE5	Interfaces between different disciplines
Resources	ORE6	Number of financial sources
Resources	ORE7	Number of contracts
Project team	OP1	Number of different nationalities
Project team	OP2	Number of different languages
Project team	OP3	Presence of a JV partner
Project team	OP4	Involvement of different time zones
Project team	OP5	Size of the project team
Methods	OM1	Incompatibility between different project management methods/tools
Trust	OT1	Trust in project team

Trust	OT2	Trust in contractor
Risk	OR1	Organizational risks

External Complexities:

Sub-ordering	Element code	Element
Stakeholders	ES1	Number of external stakeholders
Stakeholders	ES2	Variety of external stakeholders' perspectives
Stakeholders	ES3	Dependencies on external stakeholders
Stakeholders	ES4	Political influence
Stakeholders	ES5	Lack of company internal support
Stakeholders	ES6	Required local content (forced cooperation with local parties)
Location	EL1	Interference with existing site
Location	EL2	Weather conditions
Location	EL3	Remoteness of location
Location	EL4	Lack of experience in the country
Market conditions	EM1	Company's internal strategic pressure
Market conditions	EM2	Instability of the environment
Market conditions	EM3	Level of competition
Risk	ER1	Risk from environment

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End of Project Report