Comparing Project Management and Chemical Engineering - Some Observations

Raju Rao, PMP, SCPM, OPM3 Certified Professional

Abstract

Chemical Engineering is now a more century old profession and history has shown that it had to surmount many challenges before being accepted widely. Project Management as a practice started off much later seems to follow a similar trajectory. In this paper a comparison is made of the evolution of the two disciplines, understanding the areas of commonality and some concepts that project management can follow in its practice. One such practice is the concept of ‘unit operations’ which was a principal reason for the widespread use of chemical engineering. Similar to this, it is propounded that we can use the concept of a ‘universal process’ in project management which will enable it to be applied as a generic methodology and will go a long way in implementation of any project irrespective of the domain, industry or size.

Historical comparison

Chemical Engineering

The development of chemical engineering as a discipline and practice can be observed through six periods.

- (1780 -1880) The initial years: Saw the emergence of a substantial chemical industry and the new science of chemistry. (6)

- (1880 -1910) Origins of chemical engineering: A ‘Society of chemical engineers’ was first started in the UK and formal educational courses first offered by Universities in the period 1887 /1888. George Davis first postulates in a series of lectures recognizes that chemical processes could be regarded as combinations or sequences of a comparatively small number of procedures. Before 1905 many universities in the US were offering such courses and this matched the growth of chemical industry. In 1908 the American Institute of Chemical Engineers was formed. (6)

- (1910- 1945) Defining a new profession: Major focus was on education. Arthur D Little first coined the term ‘unit operations’ in 1915. Chemical engineering
courses were started in various institutions in the US, UK, South Africa, India and Japan. During this period various books were published most notable being Principles of Chemical Engineering, Perry’s Chemical Engineers’ Handbook and Chemische Ingenieur–Technik. (6)


- (1970-1995) New challenges: Stagnation in growth due to less product development from the sixties, energy prices and safety concerns and pollution control issues became threats to the growth of chemical engineering. (6)

- (1995-present) A Paradigm shift? The London communiqué signed by eighteen societies of professional chemical engineers around the world review the role of chemical engineers and considered a more holistic approach which included quality of life, employment, economic and social development, protection of the environment and encompassed the essence of sustainable development. (6)

The future looks at various areas of research: energy and natural resources processing, biochemical and biomedical engineering, (1) advanced engineering materials, electronic, photonic and recording materials & devices, environmental protection, safety and hazardous materials, cross-cutting surface and interfacial engineering and computer assisted process control and process engineering. Chemical engineering practice and profession can be expected to move beyond the concept of unit operations, reaction engineering or even a multi-disciplinary approach to solve problems.

Business models could be moving from a diversified chemical company to a provider focusing on special products through ‘Custom manufacturing’ and ‘Exclusive syntheses focused on the customer. (2) Product / Project engineering & management will become common place as compared to large scale continuous processing. The emphasis will be on organizations to focus on their core competencies and leveraging their knowledge and expertise through technology, knowledge management, partnerships and alliances.

The new chemical engineering profession will demand more generalists and fewer specialists, they will have an extended reach in their professional community, will form matrix mindsets and have a cross functional team based approach. (10)
Historically, the major events that have taken place in practice of project management can be viewed in terms of the following periods. (11)

- The 1950s

Bechtel first used the term Project Manager in their international work beginning in the 1950's. Two pioneering techniques for project planning and monitoring, namely Critical Path Method (CPM), and Project Evaluation Review Technique (PERT), were developed in the USA, but quite independently, in the late 1950s. There emerged a perceived need to appoint a Project Manager (whether an individual or an organization) to take full and undivided responsibility for achieving the project objectives. The primary technical development in project management in this period was in network techniques, which were initially concerned with planning and control of project times i.e. with project time management.
The 1960s

Project cost management (and its associated project resource scheduling), was added to project time management as a distinctive project management technique, and integration of the two was proceeding. The net effect of a decade of focus on network techniques was that project management was closely identified with, and for some was synonymous with, the use of network techniques for project planning, scheduling and controlling. Project management was still primarily identified with the construction, defence and aerospace industries. Professional project management bodies were formed independently in Europe and North America.

The 1970s

The spread of project management applications from construction, defence and aerospace happened in virtually every industry. The emergence and/or refinement of a much wider range of tools and techniques, including WBS, responsibility assignment matrices, and ‘earned value’ methods were significant developments. Matrix forms of organization became commonplace. Management of conflict on projects became an area of concern. There was an increasing recognition of the distinctive nature of project management as a vocation/profession.

The 1980s and early 1990s

There was increased efforts to represent project management as a structured discipline and approach e.g. PMI’s PMBOK (9). The management of project scope, quality, risk, human resources, communications and contract/procurement to time and cost were added as significant project management ‘functions’. There was an increased emphasis on managing the ‘front end’ of projects, including clients’ needs determination, feasibility studies, value analysis, risk management, and project startup generally. A more balanced approach was considered to managing the entire project life cycle. There was increased emphasis on product verses project life cycle costing. There was an increased focus on managing factors external to the project, particularly stakeholders and other interested parties, and physical environmental constraints. Project management came to be perceived as an appropriate methodology for responding to, and initiating change. The development of certification/registration programs for project managers received more attention.

1990s to Now

Various trends can be observed in the environment for example global competition, rapid technological change, product obsolescence, organization downsizing process improvement, e business empowerment quality / continuous improvement, measurement and inter-organizational systems. Some trends are observed in the practice of project management for example technologies supporting collaborative work,
multiple projects and project culture. The impact of the trends has been that projects have been given a more important place, the complexity recognized and there is a transformation in the way project management is practiced. (5) While lessons and methods of the past may be useful they may not be entirely sufficient to meet the challenges of today’s trends and impacts and therefore a more holistic approach has to be considered. Nowadays, the focus is around the role of project management in strategic issues, management/organizational issues and maturity, performance management and or use of resources /cost. Other areas of interest are contextualization of the applications and the creation of value for stakeholders. Project management is more focused on implementation of organizational strategy and soft skills have become more important. (13)

<table>
<thead>
<tr>
<th>Dates</th>
<th>Milestones – Development of Project Management</th>
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<tbody>
<tr>
<td>1950s</td>
<td>There emerged a perceived need to appoint a Project Manager to take full and undivided responsibility for achieving the project objectives.</td>
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<td>• The primary technical development in project management in this period was in network techniques, which were initially concerned with planning and control of project times - i.e. with Project time management.</td>
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<td>1960s</td>
<td>• PERT, PERT/COST and C/SCSC , Developments with CPM and PDM , Extensions to PERT/CPM/PDM</td>
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<td>• The Formation of Professional Project Management Bodies</td>
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<td>1970s</td>
<td>• A Proliferation of Project Management Application Areas</td>
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<td>• Writings on Project Management &quot;Applications&quot;</td>
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<td></td>
<td>• &quot;Professional Definition&quot;</td>
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<td>• Projects and the Systems Approach</td>
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<td>• Project and Matrix Organisations  Conflict Management</td>
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<td>1980s – early 1990s</td>
<td>• PMI's ESA Report</td>
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<td></td>
<td>• PMI's PMBOK</td>
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<tr>
<td></td>
<td>• Increased Emphasis on the &quot;Front End&quot; of Projects</td>
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<td></td>
<td>• Towards &quot;Product&quot; (verses Project) Life Cycle Costing</td>
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<td>• Increased Focus on Factors External to the Project</td>
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<td></td>
<td>• Project Management as a Means of Responding to, and of Initiating, Change</td>
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<td></td>
<td>• Impacts of Computer Technologies</td>
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<td></td>
<td>• Certification/Registration Programs for Project Managers</td>
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<tr>
<td>1995 to present</td>
<td>• Wider application of project management in fields other than engineering, construction and technology.</td>
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<td>• Focus on complexity of projects ,a critical examination of the theory of project management</td>
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<td>• More appreciation of the need for including risk and uncertainty</td>
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<td>• Quantitative models in project management</td>
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<td>• Use of social media</td>
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<td>• Emphasis on Soft skills in project management including leadership &amp; emotional intelligence</td>
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<td>• Business orientation of projects</td>
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<td>• New approaches or methods - agile projects , critical chain</td>
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<td>• Interface of project management and change management</td>
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Table 2 – Milestones – Project Management
Fig 1 – Dateline - Chemical Engineering & Project Management

Fig 2 – Growth of membership - American Institute of Chemical Engineers and Project Management Institute
Comments on Historical comparison

Fig 1 shows that historically project management is following the footsteps of chemical engineering. 1910-1945 was the period for defining the chemical engineering profession. Project management as a practice is still in that stage because there is a still a strong debate on whether project management is a profession by itself. It has still to reach the status reached by professional engineers since it is still not been mandatory to employ certified project managers for projects even in specific areas and if they are of certain size. It is interesting to note the similarity in sudden growth of chemical engineering and project management during sudden periods in Fig 2 -1945 -1995 for Chemical Engineering and 1990 to 2010 for Project management. There are in fact many commonalities that can be observed between the two professions and this is discussed in the next section.

Project Management & Chemical Engineering disciplines
Similarities in development

- **Commonality of processes across industrial sectors**: Earlier manufacturing processes in each industry like dyes, drugs & pharmaceuticals, bulk chemicals, plastics were studied individually and practiced as such. This was so particularly in Germany where it was understood that there are separate areas of knowledge and practice in industrial chemistry based on the domain or industry. In fact, this was a point of divergence in understanding the subject of chemical engineering as developed by professionals and academics in the US/UK as compared to Germany. A significant development in Chemical Engineering occurred when the concept of Unit Operations was introduced by Arthur D Little in 1915 in the USA. This established the commonality of physical processes in many process and chemical industries. Historically, Project Management seems to have followed a trajectory similar to chemical engineering. This can be seen starting with the use of tools and techniques like CPM, PERT and Cost Management during WW II and later on with the introduction of bodies of knowledge and common processes when project management standards were formulated in the US/UK in the 1980s. Earlier, project management as a subject was specific to different domains and industries whether it be construction, product development or R&D, manufacturing, social sector, etc. With the introduction of various standards in project management, the commonality among various domains was understood and this also became the driving force for its growth as a potential new profession.

- **Struggle for acceptance as a generic discipline**: The development of chemical engineering as a profession and practice forms an interesting story probably matching elements of intrigue, suspense and struggle which are probably found only in mystery novels. Initially, chemical engineers found it difficult to establish their uniqueness and worth as the need for a new profession was questioned and the role
played by them was unclear. With the rapid growth of the American chemical industry around the turn of the century, the gap between laboratory processes and full-scale industrial production needed to be bridged. American chemical industry was fundamentally different from the Germans with the former focusing on bulk chemicals and large scale production and the latter dealt predominantly with fine chemicals produced in batch processes. Industrial chemists in America found it easier to adopt chemical engineering as a practice and profession though the American Institute of Chemical Engineers (AICHE) faced competition from the older and powerful American Chemical Society (ACS). (6) Faced with the possibility of direct conflict with the ACS, the AICHE decided on a course of action designed to minimize rivalry and remain on good of terms and followed an attitude of cooperation rather than competition. This approach paved the way for a diplomatic and negotiated solution to the problem which was probably a significant move considering that later on chemical engineering came to be accepted as a discipline in its own right and responsible for its growth across the world.

Project Management has followed a similar pattern of development, first it was predominantly being used in construction and engineering sectors(11) and only later on being applied in other areas like information technology , manufacturing, etc. and now newer applications are being found in diverse areas like hospitality, entertainment, etc. In many of the newer applications the work being done in project mode is still not construed as project management and this delimits its wider acceptance as a generic discipline. Multiple bodies and standards in project management have emerged with differences in content and its approach to evangelize the knowledge and practice. Only recently a unified ISO standard at high level has been established for project management. There is a still a debate on whether project management is a profession or a management discipline. The challenge of acceptance of project management as a methodology in non-traditional sectors continues and in that sense its similarity with development Chemical Engineering can be observed.

- Dates: Chemical Engineering started in the early 1900s and now more than 100 years old profession. Project Management started in 1950s and that sense it is clear 50 years behind and relatively younger profession. Comparing the two as in Fig 1 it can be seen that their trajectory are similar and overlap with the stage of defining the profession that occurred for chemical engineering now happening for project management with possibly at the end of that phase.

- Project & Product orientation: At its inception and during the last century, the discipline of Chemical Engineering has largely been project oriented. The concept of unit operations became perceptible and useful more for large scale and continuous type production processes rather than smaller batch type industrial production. However, recently there has been some interest in applying chemical engineering processes for product development particularly when looking at customized
solutions for individual customers or businesses. (10) The trend in the future will be to move towards producing specialty products which will be based on custom engineering / manufacturing and exclusive synthesis focused on the customer. Product / Project engineering & management will become common place as compared to large scale continuous processing.(2)

Project management has largely been applied in project situations whether it is construction, engineering, information technology or social initiatives. To some extent, it has also been used in product development, as part of R & D. There is an attempt to align it with product management which is a discipline by itself and has a different emphasis than project management. Many organizations in the IT sector struggle to utilize project management principles effectively for product development within the organization against implementing a project for an external customer. In future one would expect project management being applied for more product situations in addition to large scale projects.

Unit Operations and Processes in Chemical Engineering

Unit Operations

The term ‘unit operations’ was coined by Arthur D Little, a consultant in USA in 1915 in a report submitted to the President of MIT, USA. The approach sharply delineated the domain of chemical engineering and distinguished it from industrial chemistry and mechanical engineering. The unit operation concept was the key in establishing the uniqueness and independence of a new field and profession. (6)

The concept of unit operation has been used to simplify the study of chemical engineering. Instead of having to study each chemical industry separately, the chemical engineer can merely learn the principles basic of the different unit operations which can be applied no matter what the chemical field or industry maybe. (7) Examples of unit operations originally considered by Arthur D Little were pulverizing, dyeing, drying, crystallizing, filtering, evaporation, electrolyzing, etc. Later on it the list was made more comprehensive and others e.g. fluid flow, heat transfer, distillation, humidification, gas absorption, sedimentation, classification, agitation and centrifugation.(3) They may be inter related example heat mass transfer and fluid flow combined.

Unit operations limit themselves to the physical changes that take place in a process and the versatility of chemical engineering is due to practice of breaking up a complex process into individual steps. The philosophy is that processes are identical in fundamentals regardless of the material being processed and only vary due to complexity due of conditions e.g. temperature pressure etc. and different material of construction. In recent years newer processes from varying fields have been added e.g. chemical vapour deposition, extrusion, membrane processes, bio-separation etc. (4)
Unit Processes and Chemical Reaction Engineering

Along with development of unit operations a parallel concept called Unit Processes was used to classify chemical processes. Shreve is considered as the originator of this philosophy but became more popular because of the book by Groggins. (8) Therefore nitration, halogenations, oxidations, reductions, alkylation, sulphonation, hydrogenation, amination etc. formed separate unit processes and were studied as such. This was natural considering the close affinity of chemical engineering to industrial chemistry at its inception. Chemical reaction engineering is that engineering activity concerned with the exploitation of chemical reactions on a commercial scale. Its goal is the successful design and operation of chemical reactors, and probably more than any other activity, it sets chemical engineering apart as a distinct branch of the engineering profession. Gradually however, the subject of chemical reaction engineering has largely replaced the unit process concept. (12)

‘Universal’ processes in project management?

The historical development of chemical engineering and project management shows many parallels. Most striking similarity is the universal application of basic processes irrespective of domain or field. In project management we may have some difficulty in using the word ‘operation’ as it can have a different meaning particularly when we need to differentiate between a project and an operation. Therefore, possibly we can use the term ‘universal process’ to denote common processes used in project management. Processes of PMBOK guide are potentially ‘universal processes’ and therefore Creating WBS, Develop a schedule, Acquiring a team, control project scope and closing a project, etc. would all fall under this category. In such a case the take-away will be that for any project to be implemented common processes have necessarily to be applied and accordingly knowledge and skills are to be acquired by them or contracting with a group or organization that have such capabilities.

Elaborating further, ‘universal processes’ would apply whether the project is in petrochemical, information technology, market research, a wedding, a movie or a solar energy installation. In effect it could apply to any type of project. One of the main objectives of standards like the PMBOK guide or those similar in project management is to establish the universal nature of common project processes but it is a moot point whether in practice the industry or business sector is perceiving it and applying in that way. In the author’s experience except for some fields where project management is well established (e.g. power, technology, manufacturing, etc.) and commonality of processes is observed there are other fields (e.g. social sector, marketing, entertainment, events, academic, etc.) where the learning is anecdotal or empirical resulting in re-inventing the wheel and giving credit or perceiving it as new or innovative moment when in fact routine project management practice has been deployed. There is a lot of ground to be covered before project management processes can truly be considered a unified
process of implementation (similar to one how one would consider other professions e.g. accounting) and in this regard the concept of a 'universal process' would go a long way in evangelizing the application of project management in non-traditional sectors.

<table>
<thead>
<tr>
<th>Concept in Chemical Engineering</th>
<th>Corresponding concept in Project Management</th>
<th>Examples in Project Management</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit Operations</td>
<td>Generic Project Management processes</td>
<td>Develop Project Charter, Develop Schedule*</td>
<td>Applies to most projects</td>
</tr>
<tr>
<td>Unit Processes</td>
<td>PM process more specifically applied in a domain</td>
<td>Requirements Management, Quantitative Risk Management*</td>
<td>Processes apply to only certain projects</td>
</tr>
<tr>
<td>Chemical Reaction Engineering</td>
<td>Set of processes for a domain</td>
<td>Software development, Crisis / Disaster Management, New product development</td>
<td>Unique or Different project situations</td>
</tr>
<tr>
<td>Identifying Unit Operations / Processes for manufacturing / scaling-up a product</td>
<td>Identifying appropriate PM processes / formulating methodology for a project</td>
<td>Select relevant processes from PMBOK guide* or equivalent as applicable</td>
<td>Depends on type of project, domain and complexity</td>
</tr>
<tr>
<td>Cross functional knowledge and practice with other engineering disciplines, environment, stakeholders</td>
<td>Interdisciplinary knowledge and skills with other management areas (e.g. HR, Quality), environment, stakeholders</td>
<td>Processes beyond project management standards (e.g. PMBOK guide*)</td>
<td>Holistic and broad-based approaches</td>
</tr>
</tbody>
</table>

*PMBOK Guide 5th Edn (9)

Table 3 – Mapping Project Management with Chemical Engineering

Conclusions

Chemical engineering as a discipline started off in the early 1900 and progressed through stages of definition of a profession, sustained growth and further challenges in maintaining it. The main conceptual milestones have been unit operations, transport phenomena and its interface with biological sciences.
Project management started off much later in the early 1950s principally with time management tools like CPM /PERT to which were first cost was cost and thereafter other knowledge areas. Subsequently soft skills got introduced as practice areas. At present, the focus is on understanding stakeholders, implementation of organizational strategy through projects and improving the maturity of organizations. Historically, project management has still to come of age as a profession compared to chemical engineering since in case of the former there is a still a debate on whether it is truly a profession as compared to the latter which is on a more established footing.

- Various similarities can be observed in the growth of chemical engineering and project management disciplines. There is commonality of processes across industrial sectors, the struggle for acceptance as a generic discipline, the date-wise similarities of happenings and the interface with product development and management.

- A principal development in chemical engineering has been emergence of the concept of 'unit operations' and this led to its widespread development. Other milestones in its development included the understanding of transport phenomena the interface with biological sciences.

- The concept of 'unit operation' as in chemical engineering replicated in project management. This could be termed a ‘universal process’ and the concept will be helpful in wide-spread of project management as a discipline. Many of the concepts in chemical engineering e.g. unit operations, unit processes and reaction engineering can be mapped to equivalent processes in project management.

- Future trends in chemical engineering looks at a more holistic approach to use of engineering in relation to stakeholders, society and this is perceptible in its approach in the interface with energy / environment, materials and biological sciences, There is also an orientation to move from large scale processing to more customized solutions focused on the customer. Project management as a discipline is adapting to global trends and is becoming a wider field embracing soft skills along with its interface with stakeholders and society.

References

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   http://pubs.acs.org/cen/education/7923/7923education.html


(9) PMBOK Guide 5th Edn. (A Guide to the Project Management Body of Knowledge), Project Management Institute, USA


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About the Author

Raju N Rao

Chennai, India

Raju N Rao is Founder of Xtraplus Solutions which is involved in consulting and training in Project Management. Raju has presented papers at Global Congresses and has been involved in the development of many standards of PMI particularly OPM3. He often writes for project management journals and is coauthor of two books - Project Management Circa 2025 and Organizational Project Management. He is a PMP, SCPM and a PMI certified OPM3 Professional. He was a Founder Board member of PMI Chennai Chapter, has been on the Leadership Team for Awards for PMI India and Global Advisory Board for OPM3 Professionals. Raju can be reached at rao.raju@gmail.com