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Scientific Management and Current R&D Management Principles and Practices

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ABSTRACT: The assertion that scientific management is anathema to modern R&D management is examined in detail. Scientific management is discussed, not as the scourge of contemporary management, but in light of its historical context, the kinds of problems it intended to solve, and the problems it created. Furthermore, a review of the principles currently employed in R&D management is also conducted. The key is to understand how the transformation from scientific management to current management principles and techniques occurred and, more importantly, why it took place. With this paradigm shift comes an appreciation for the goals of scientific management and the principles of modern R&D management, an understanding of how R&D management has evolved, and an insight into how it may evolve in the future.

KEYWORDS: • Frederick Taylor •Job Enlargement •Job Enrichment •R&D Management •Scientific Management

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MISCELLANEOUS CONSIDERATIONS

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INTRODUCTION

The assertion that scientific management is anathema to modern R&D management is examined in detail. Scientific management is discussed, not as the scourge of contemporary management, but in light of its historical context, the kinds of problems it intended to solve, and the problems it created. Furthermore, a review of the principles currently employed in R&D management is also conducted. The key is to understand how the transformation from scientific management to current management principles and techniques occurred and, more importantly, why it took place. With this paradigm shift comes an appreciation for the goals of scientific management and the principles of modern R&D management, an understanding of how R&D management has evolved, and how it may evolve in the future.

DEFINITION OF SCIENTIFIC MANAGEMENT

According to Taylor, the goal of management is to ensure the maximum possible prosperity for both the employer and the employee.[1] By this, it is meant that the employer's profits are maximized through low labor costs, while at the same time workers earn high wages. Although these two goals appear contradictory, the idea is to develop each worker so that they are working at peak efficiency, subject to the physical limitations of a job.[2]

Scientific management aims to do away with underworking, or *soldiering*, where workers deliberately work slowly to avoid doing a full day's work.[3] The reasons for soldiering are as follows:[4]

- The workers believe that increases in individual productivity will increase unemployment;
- Management systems are defective, so soldiering is essential for workers to protect their best interests; and
- Inefficient rules of thumb are used, which ensure that workers waste their effort by performing tasks inefficiently.

According to Taylor, older management systems allowed each worker to be responsible for doing their job according to how they saw fit, with little help or advice from management.[5] Taylor asserted as a general principle that workers in the mechanical arts were generally incapable of fully understanding the work processes that they were hired to perform, either because of a lack of education or due to insufficient mental capacity.[6] In other words, the purpose of management is to "take over and perform much of the work which is now left to the men; almost every act of the workmen should be preceded by one or more preparatory acts of management which enable him to do his work better and quicker than he otherwise could."[7] Taylor stated that three questions are particularly relevant in discussing scientific management, including:[8]

- How do the principles of scientific management differ from ordinary management?
- Why does scientific management produce better results than ordinary management?
- How important is finding the right person to lead a company?

According to Taylor, at the time, the best management in ordinary use was the management that allowed workers to give their best initiative in return for some special incentive.[9] Under this management style, success depends upon the workforce's hard work, goodwill, and ingenuity. In scientific management, the purpose of management is to gather the knowledge previously possessed by the workers, then classify, tabulate, and reduce this knowledge to rules, laws, and formulae that can help workers perform their daily tasks.[10] In summarizing this knowledge, management takes on the additional responsibilities of:[11]

- Scientifically describing each worker's activities;
- Selecting, training, teaching, and developing each worker individually;
- Cooperating fully with the workforce to ensure that the work is accomplished effectively; and
- Sharing the work almost equally between management and the workforce.

From Taylor's perspective, the most prominent element of scientific management is that the work of every employee is planned out at least one day in advance, where the worker receives written instructions describing the tasks to be accomplished and the means to achieve them.[12] One of the critical advancements proposed by scientific management is that workers need rest to achieve maximum efficiency.[13] The key issue is that when workers are herded into gangs, each person is far less efficient than when their ambition is stimulated.[14] The fact that the efficiency of a group of workers is not better than the weakest among them leads one to

[1] FREDERICK W. TAYLOR, THE PRINCIPLES OF SCIENTIFIC MANAGEMENT (Dover Publications, Inc. 1997 [Harper & Brothers Publishers 1911]).
[2] *Id.*
[3] *Id.*
[4] *Id.*
[5] *Id.*
[6] *Id.*
[7] *Id.*
[8] *Id.*
[9] *Id.*
[10] *Id.*
[11] *Id.*
[12] *Id.*
[13] *Id.*
[14] *Id.*

believe that Taylor may have been ahead of his time because he foretold the coming of Goldratt's theory of constraints by understanding the productive limitations of bottlenecks.[15]

Thus, the significance of scientific management is that it enforces the standardization of methods, the adoption of best implementation and working conditions, and the cooperation of both management and the workforce.[16] It is the function of management to act as teachers, showing each new worker the most effective ways of performing their job. According to Taylor, it is the responsibility of management to help slower workers rise to the desired level of performance.[17] Scientific management was successful in its day because managers and workers were supposed to work together to achieve optimal results.[18]

According to Taylor, the advantages of scientific management from the worker's point of view were that the employees received higher than average wages, a shorter work day, each employee was given special care, making them feel important, and standardized rest periods were established.[19] From the company's perspective, the benefits of scientific management resulted from substantial improvements in product quality, a reduction in the cost of inspection, and friendly relationships with employees.[20]

One caveat that Taylor readily acknowledged was that these benefits were strictly confined to elementary types of work.[21] According to Taylor, scientific management is even more beneficial for individuals prone to discovering methods independently.[22] When intelligent and educated people are responsible for solving many problems, they tend to group problems and then search for the laws or rules that will guide them to a solution.[23] Under scientific management, it is the duty of management to find and teach impartially the workforce the most efficient ways of doing things.[24] Thus, scientific management rests upon substituting a science for the individual judgment of employees, the scientific selection and development of each worker, and the cooperation of management and workers to work under scientific laws rather than succumbing to the nuances of individual employees.[25]

CRITICS OF SCIENTIFIC MANAGEMENT

According to Russell and Taylor, scientific management came into prominence with the rise of heavy manufacturing in the late 1880s.[26] The approach broke down tasks into their essential elements, including the actual motions of a worker, and then eliminated nonessential motions. Russell and Taylor then observed that scientific management suggested that these tasks be divided among several workers so that the employer could hire many cheap, unskilled laborers.[27] The advantage of scientific management was increased output at lower labor costs, while the disadvantage was that workers became bored and dissatisfied with the extensive repetition of simple tasks.[28] According to Russell and Taylor, the primary motivator of scientific management was increased pay.[29] The repetitive physical motion resulted in mental and physical fatigue, increased tardiness, turnover, absenteeism, and dissatisfaction.[30]

From Bell's perspective, the ends of capitalism consisted solely of production and efficiency.[31] One of the basic assumptions of scientific management was that status should only be based on superior knowledge, rather than nepotism or superior financial power.[32] The idea behind scientific management was to find the best way to do something, and by adhering to these natural laws, remove the antagonism between the workers and the employer, namely the conflict between what is fair and unfair.[33] The result was that humanity was replaced with *hands* and *things* arranged in minute detail, where the measure of a person's contribution rested on one's ability to move the most things in the shortest period.[34]

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[15] ELIYAHU M. GOLDRATT, & JEFF COX, THE GOAL: A PROCESS OF ONGOING IMPROVEMENT (North River Press 40th Anniversary ed. 2012).
[16] Frederick W. Taylor, *supra*, note 1.
[17] *Id.*
[18] *Id.*
[19] *Id.*
[20] *Id*.
[21] *Id.*
[22] *Id.*
[23] *Id.*
[24] *Id.*
[25] *Id.*
[26] ROBERTA S. RUSSELL, & BERNARD W. TAYLOR III, OPERATIONS MANAGEMENT: FOCUSING ON QUALITY AND COMPETITIVENESS (Prentice-Hall, Inc. 1997).
[27] *Id.*
[28] *Id.*
[29] *Id.*
[30] *Id.*
[31] DANIEL BELL, THE COMING OF POST-INDUSTRIAL SOCIETY: A VENTURE IN SOCIAL FORECASTING (Basic Books 25th Anniversary Edition 1999).
[32] *Id.*
[33] *Id.*
[34] *Id.*

George and Jones stated that scientific management was a set of principles that accentuated job simplification and specialization.[35] Management is responsible for determining the best way to perform a job. According to George and Jones, scientific management was instrumental in promoting worker effectiveness and productivity by simplifying a job and encouraging specialization while performing time and motion studies.[36] The problem with scientific management was its greatest strength. Workers lost control over their work behaviors, viewing their work as depersonalized, meaningless, and monotonous.[37] These feelings, in turn, were the primary reason for the loss in productivity.

Lee and Schniederjans observed that scientific management must be viewed in its historical context, where the practice of management was formalized into a science.[38] Schroeder observed that the aim of scientific management was to use a scientific approach to discover the best work methods by:[39]

- Observing present work methods;
- Developing an improved work method through scientific measurement and analysis;
- Training workers in the new method; and
- Continuing feedback to management on the work process.

The attacks against scientific management have come from labor unions, workers, and academics, typically because the approach was misapplied, being used by management as a justification for speeding up the production process.[40] Even so, Schroeder observed that Taylor believed the two primary reasons for reduced output were the fear of a worker losing their job and the unwillingness of management to pay for higher productivity levels.[41]

Some misconceptions about scientific management were that it was a piece-rate system, where time studies and efficiency reports were the tools to drive workers into subsistence.[42] In contrast, Schroeder argued that, according to Taylor, workers and managers need to work together to eliminate waste and improve productivity by applying scientific management.[43] Schroeder found it interesting that Taylor developed scientific management as a means of reducing, or even eliminating, labor-management strife.[44] Schroeder also stated that repetitive jobs, work specialization, and the division of labor started before Taylor's time, since it could potentially treat humans like machines.[45] The criticism has some validity, for scientific management treats workers as economic individuals where psychological and social variables are irrelevant.[46]

The real question is whether scientific management is applicable today. According to Schroeder, jobs are still specialized, time motion studies still have validity, but efficiency and waste removal are more critical than ever.[47] The whole notion of total quality and just-in-time is predicated on removing waste. Thus, with some modifications, scientific management encourages workers to develop strong social relationships while continuously improving production processes, which remains valid.[48]

JOB ENLARGEMENT AND JOB ENRICHMENT

According to George and Jones, there was an effort in the 1940s and 1950s to counteract the disadvantages of scientific management through job enlargement.[49] The idea behind job enlargement is to increase the number of tasks performed by a worker while keeping all tasks at the same difficulty level. This is also known as *horizontal job loading* because the job content is expanded, but the difficulty remains.[50] Job enlargement intends to increase the intrinsic motivation of the workforce. However, the results were mixed, where some firms experienced productivity increases, while other companies reported little or no gains.[51]

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[35] JENNIFER M. GEORGE, & GARTH R. JONES, UNDERSTANDING AND MANAGING ORGANIZATIONAL BEHAVIOR (Pearson Education Limited 2012).
[36] *Id.*
[37] *Id.*
[38] SANG M. LEE, & MARK. J. SCHNIEDERJANS, OPERATIONS MANAGEMENT (Houghton Mifflin Company 1994).
[39] ROGER G. SCHROEDER, OPERATIONS MANAGEMENT: DECISION MAKING IN THE OPERATIONAL FUNCTION (McGraw-Hill, Inc. 1993).
[40] *Id.*
[41] *Id.*
[42] *Id.*
[43] *Id.*
[44] *Id.*
[45] *Id.*
[46] *Id.*
[47] *Id.*
[48] *Id.*
[49] Jennifer M. George, & Garth R. Jones, *supra*, note 35.
[50] *Id.*
[51] *Id.*

In response, job enrichment was promoted in the 1960s, where jobs were designed "to provide opportunities for worker growth by giving workers more responsibility and control over their work."[52] Job enrichment is also known as *vertical job loading* since workers are given some of the responsibilities that were previously the domain of management. According to Herzberg, a worker's motivational needs are satisfied by experiencing autonomy on the job and being responsible for the work.[53] Several ways to enrich jobs include allowing workers to:[54]

- Plan their own work schedules
- Decide how the work should be performed
- Check their own work
- Learn new skills

Like job enlargement before it, job enrichment aims to increase workers' intrinsic motivation by giving them more responsibility so that they feel more competent and have more control over their work behavior.[55]

It should be noted that not all workers want their jobs to be enlarged or enriched, and that when some jobs are either enlarged or enriched, there is a decline in productivity. George and Jones pointed out that Subway sandwich shops can make large numbers of sandwiches because the jobs are simplified and specialized.[56] The fact is that job enrichment may increase the time to serve customers, and therefore reduce the effectiveness of the organization.

JOB CHARACTERISTICS MODEL

Hackman and Oldman identified several job characteristics contributing to intrinsically motivating workers, including:[57]

- Skill variety;
- Task identity;
- Task significance;
- Autonomy; and
- Feedback.

The idea is that good performance makes workers feel good, and good feelings reinforce good performance. Furthermore, good performance reduces costs, improves customer relations, and helps a company achieve and maintain a competitive advantage.[58]

Table 1. Elements of Job Design

Task Analysis	Worker Analysis	Environmental Analysis
Description of the tasks to be performed	Capability requirements	Workplace location
Task sequence	Performance requirements	Process location
Function of tasks	Evaluation	Temperature and humidity
Frequency of tasks	Skill level	Lighting
Criticality of tasks	Job training	Ventilation
Relationships with other jobs and tasks	Physical requirements	Safety
Performance requirements	Mental stress	Logistics
Information requirements	Boredom	Space requirements
Control requirements	Motivation	Noise
Error possibilities	Number of workers	Vibration
Task duration(s)	Levels of responsibility	
Equipment requirements	Monitoring level	
	Quality responsibility	
	Empowerment level	

[52] *Id.*
[53] FREDERICK HERZBERG, WORK AND THE NATURE OF MAN (World Press 1969).
[54] RICKY W. GRIFFIN, TASK DESIGN: AN INTEGRATIVE APPROACH (Scott Foreman Press 1982).
[55] Jennifer M. George, & Garth R. Jones, *supra*, note 35.
[56] *Id.*
[57] J. RICHARD HACKMAN, & GREG R. OLDMAN, WORK REDESIGN (Addison-Wesley Press 1980).
[58] Jennifer M. George, & Garth R. Jones, *supra*, note 35.

Russell and Taylor observed that the elements of the job characteristics model in designing jobs are task analysis, worker analysis, and environmental analysis.[59] These elements are described in Table 1.

Task Analysis

Task analysis determines how to do each task and how the tasks fit together to create a job.[60] This includes describing the particular tasks within a job to discover the most efficient sequence, duration, frequency, and relationship with other tasks. A task analysis needs to be sufficiently detailed, resulting in step-by-step procedures for the job under consideration. The performance requirements of a task is the time needed to complete the task, the accuracy in performing the task to specifications, the level of productivity or output, and the quality performance.[61]

Worker Analysis

Worker analysis is concerned with the characteristics that a worker must possess to satisfy the job requirements, the work responsibilities of the worker, and how the worker is to be rewarded.[62] While some jobs require physical strength, others demand mental expertise. Physical requirements are determined to ensure they are not excessive, resulting in a job redesign.[63]

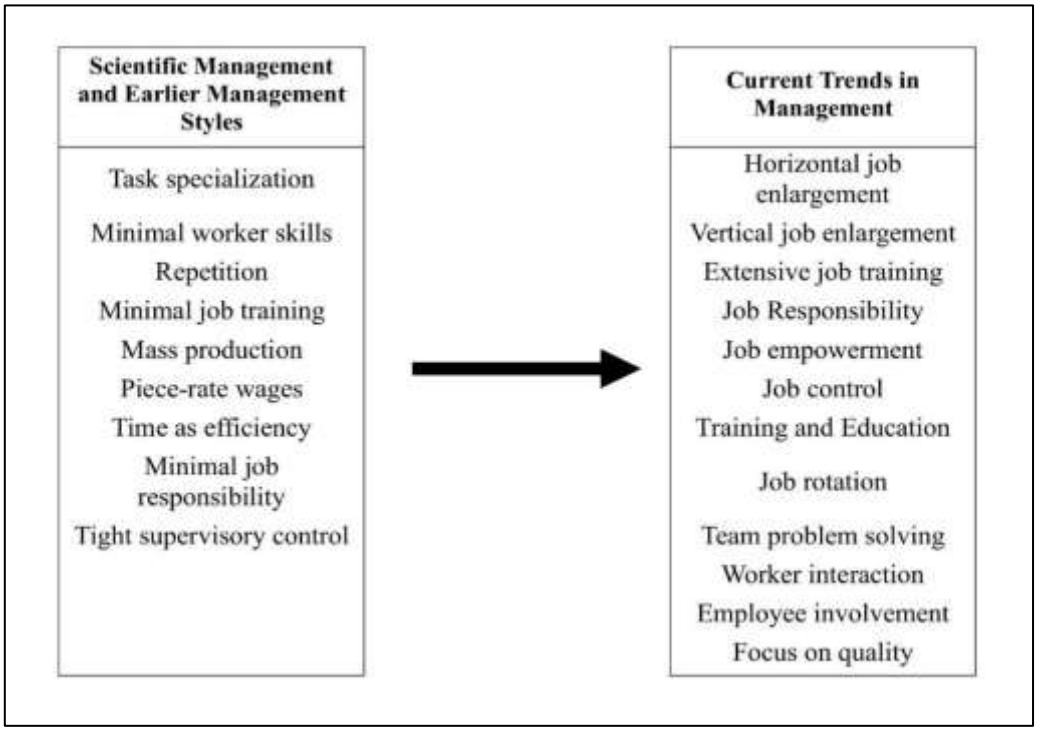

Figure 1. The Evolution of Job Design

Environmental Analysis

Environmental analysis refers to the physical location of a job in a production or service setting, where the job is performed.[64] These conditions include the proper temperature, lighting, ventilation, and noise. Some jobs demand extensive lighting, such as engraving, while others require proper ventilation to reduce dust levels and other irritants. For still other jobs, a large amount is space is needed around the job area to ensure the safety of the workers.

Evolution of Jobs

It is evident that the nature of jobs is evolving, not only horizontally but also vertically. Companies committed to total quality understand that workers at all levels of an organization desire more responsibility and power over what they do.[65] The movement from mass production to small batch production has forced firms to design work to be more flexible by reducing specialization. If

[59] Roberta S. Russell, & Bernard W. Taylor III, *supra* note 26.
[60] *Id.*
[61] *Id.*
[62] *Id.*
[63] *Id.*
[64] *Id.*
[65] *Id.*

scientific management with the management styles of the 1900s and the current trends are examined in an evolutionary light, Figure 1 demonstrates how jobs have changed over the years.[66] What is evident from Figure 1 is that jobs and workers are becoming more individualized and more autonomous, as the needs of customers become more pronounced, and as workers demand more freedom of what they do and how they do it.

RESEARCH AND DEVELOPMENT MANAGEMENT

Potential Misunderstandings

Burgelman and Sayles observed systematic differences between how research is conducted on a business or corporate level.[67] Corporate researchers tend to see themselves as on the frontier of science, while business researchers are more entrepreneurial, attempting to link technological solutions to market needs. Even so, difficulties arise when innovation is perceived as a linear process, or viewed in terms of technological breakthroughs, where an isolated change, rather than a process, is all that occurs.[68] Table 2 lists some results that can occur when innovation is misperceived.

Table 2. Problems with a Partial Perspective of Innovation

Seen As . . .	The Result Can Be . . .
Strong R&D capability	Technology that fails to meet user needs is not accepted.
Province of specialists in white coats	Lack of involvement of others and a lack of key knowledge and experience input from other perspectives.
Meeting customer needs	Lack of technological progression leads to the inability to gain a competitive advantage.
Technology advances	Producing products the market does not want, or designing processes that do not meet the user's needs.
Province of large firms	Weak or small firms that are highly dependent on large customers.
Only about breakthrough changes	Neglect the potential of incremental innovation. Also, the inability to secure and reinforce the gains from radical change, because incremental improvements are not working well.
Only associated with key individuals	Failure to utilize the creativity of other employees who are not officially engaged in research and development.
Only internally generated	The "not invented here" effect, where good ideas from the outside are resisted or rejected.
Only externally generated	Innovation becomes a matter of filling out a shopping list of needs from the outside, with little internal learning and development of technological competence.
Only concerning single firms	Excludes the possibility of various forms of inter-organizational networking to create new products, streamline shared processes, etc.

Can R&D Be Managed?

The perception is that managing a research and development organization is like herding stray cats. Tidd and Bessant argued that there is no easy recipe for success, but that there are choices to be made about how resources are used.[69] In essence, this is a management question. Over time, organizations develop ways of doing things, or routines, that are reinforced by repetition.[70] They

[66] *Id.*
[67] ROBERT A. BURGELMAN, & LEONARD R. SAYLES, INSIDE CORPORATE INNOVATION (Free Press 1988).
[68] JOE TIDD, & JOHN R. BESSANT, MANAGING INNOVATION: INTEGRATING TECHNOLOGICAL MARKET AND ORGANIZATIONAL CHANGE (John Wiley & Sons, Inc. 2012).

[69] *Id.*
[70] *Id.*

emerge as a result of repeated behaviors learned because they work well. According to Tidd and Bessant, the routines make organizations different because they provide a firm with a personality.[71] How a company manages innovation differentiates it from its peers. They are specific to a given organization because they are learned through time and are difficult to acquire.

Core capabilities exist in the management of innovation. First, there is a need to search the environment for technical and economic clues to trigger change.[72] Next, the firm's business strategy and innovation must be a good fit. Since there are limits to a company's technological base, difficulties can arise in transferring technology or creating it in-house. Furthermore, some effort must be made to explore and select a suitable response that conforms to the company's business strategy, ensuring that management and the employees accept the implementation of new products and/or processes.[73] Whether or not an innovation is practical, it needs to be evaluated so that lessons are learned and new behaviors, routines, and processes can thrive.

SUCCESSFUL R&D MANAGEMENT

The following five critical phases in ensuring that R&D management are:[74]

- Scanning Phase;
- Strategy Phase;
- Resourcing Phase;
- Implementation Phase; and
- Learning and Reinnovation Phase.

Pictorially, Figure 2 demonstrates how managing innovation works.[75]

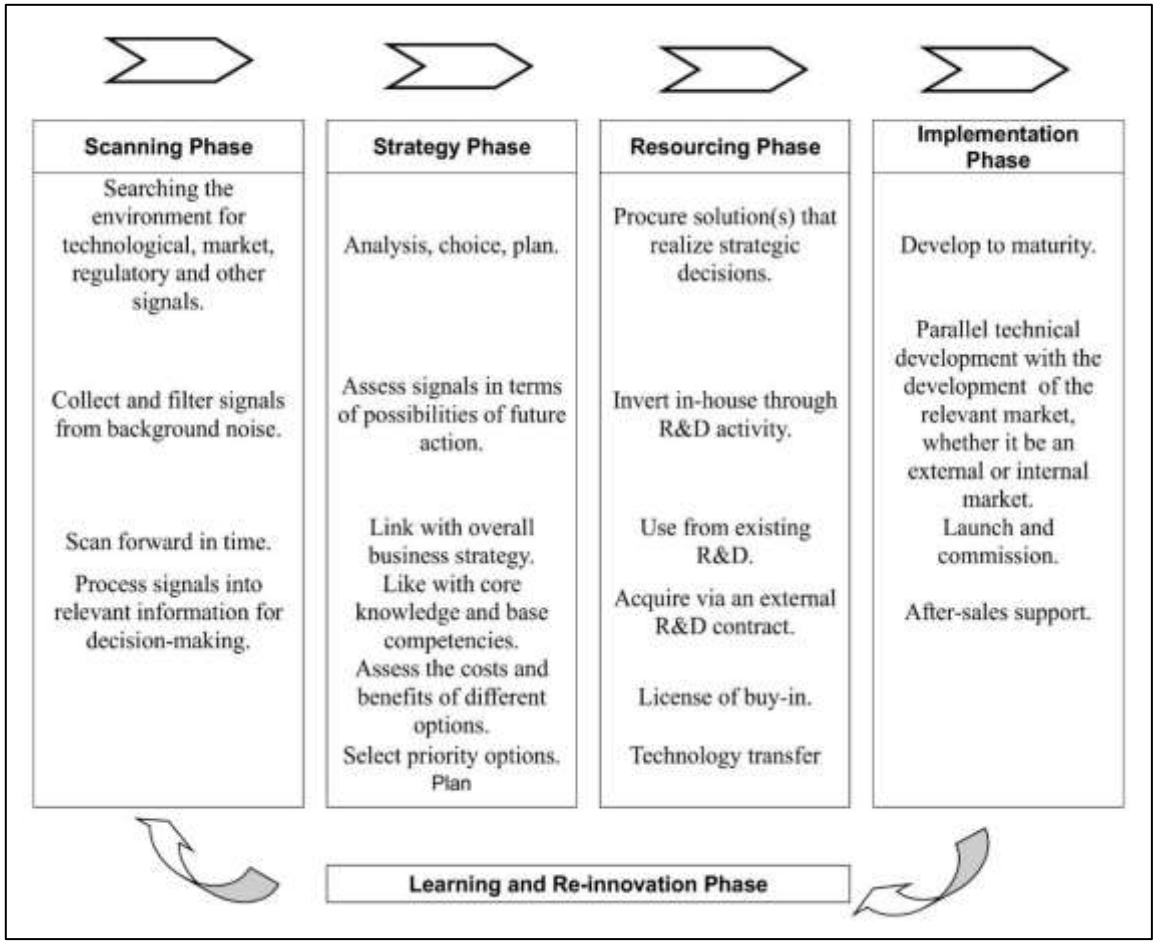

Figure 2. Routines Underlying the Process of Innovation Management

[71] *Id.*
[72] *Id.*
[73] *Id.*
[74] *Id.*
[75] *Id.*-

Scanning Phase

In this phase, R&D management is scouring the environment, looking for signals that indicate that change is occurring.[76] This includes changes in technological opportunities or differences in requirements due to legislative pressure or action by competitors. Innovation is usually the result of various forces working in unison to produce a particular change.[77] The key to successful R&D management is to have well-defined mechanisms for identifying, processing, and selecting the relevant information from an environment that may or may not be hostile to the organization.

Strategy Phase

Since innovation is risky, an organization needs to select a variety of technological opportunities that fit the company's overall business strategy.[78] This phase aims to resolve the innovation so that it can be processed successfully. According to Tidd and Bessant, the three inputs that feed the strategy phase are the flow of signals of possible technological and/or market opportunities, the technological competence of the firm, and whether the innovation fits the business.[79] For example, if a firm is acquiring a business where customer choices are critical, then the innovation may make sense, while if customers are commodity-driven, then the innovation may work at cross purposes with the company's strategy. Thus, the purpose of R&D management is to ensure a precise alignment between the innovation and the firm, so that a strategic advantage can be achieved.[80]

Resourcing Phase

The resourcing phase is concerned with combining new and existing knowledge within or outside an organization.[81] Essentially, this phase is a first draft of a solution that may undergo significant alteration as the solution is implemented.[82] If invention is thought to be a combination of ideas, then one of the purposes of R&D management is to engage in creative problem solving, or at least to create conditions where creativity can flourish. One of the constraints inhibiting R&D management is the need to balance the open-ended environmental conditions that promote creativity with the ruthless reality of the business world.[83] The challenge of R&D management is optimizing a given technology's use. The key is to find, select, and transfer technology from the outside to inside a firm without engaging in a simple shopping transaction.[84]

Implementation Phase

This phase is the heart of an innovation process, and is where the skill of R&D management comes into play.[85] Since this is where most of the time cost and commitment are encountered, this is where R&D management more closely resembles what is known as ordinary management. Tidd and Bessant observed that it is essential for a research and development team to work with the marketing, sales, and manufacturing departments so that different knowledge sets can be brought to bear on the inevitable problems that appear.[86] While problem-solving is associated with developing an innovation, a parallel set of activities is also associated with preparing a market. Since the process collects information and solves problems, an ongoing dialogue among departments is critical.

From a marketing perspective, the key is to anticipate customer responses, and to design a product so that it meets, or even exceeds, the latent requirements of a customer.[87] R&D management is therefore predicated on successful change management, by stressing communication, involvement, and intervention to minimize resistance to change or market friction.[88]

Learning and Reinnovation Phase

The outcome of an innovation is a new cycle, even if a product fails.[89] The idea is to reinvent, or build upon the successes and failures of the past. There is a real need to capture the hard learned lessons of the past, and then use this information to promote successful learning. According to Tidd and Bessant, successful innovation or R&D management involves:[90]

[76] *Id.*
[77] *Id.*
[78] *Id.*
[79] *Id.*
[80] *Id.*
[81] *Id.*
[82] *Id.*
[83] *Id.*
[84] *Id.*
[85] *Id.*
[86] *Id.*
[87] *Id.*
[88] *Id.*
[89] *Id.*
[90] *Id.*

- Taking a strategic approach to innovation and its management
- Developing and using an effective implementation mechanism and structures
- Developing and extending a supporting organizational context for innovation
- Building and maintaining external linkages

These are the *hows* of managing a particular innovation, ensuring that each notion is geared to either making an innovation part of an organization or rejecting it as inappropriate.

CONCLUSION

So the reason why scientific management is an anathema to R&D management is that the former exerts a significant amount of control on an uneducated workforce, while the latter seeks to exploit the inherent creativity of an individual and then help that person focus their creativity on the problems facing the organization. Furthermore, R&D management is not necessarily presumptuous, as it always explicitly specifies the nature of the firm's problems. No matter how well-intended, scientific management seems to assume that managers are the change agents within an organization, while R&D management places the responsibility for change on the worker.

With that said, it should not be forgotten that scientific management exists as part of the evolutionary chain, beginning with more or less unorganized work gangs. Scientific management sought to maximize the workers' efficiency, assuming they were motivated strictly by financial gain. Later research discovered that workers are more than mere automatons whose sole purpose is to do the bidding of their superior masters. This is called management. Workers are human beings, capable of higher learning, and even creative expression. R&D management comes to grips with human potential and attempts to foster creativity so that the waves of creative destruction continuously crash on the beaches of innovation, thus ensuring a hopefully better life for us all.

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