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# Re-engineering transport systems

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Abstract:

It is not enough for researchers and developers to create new products and processes; they should also consider how to get their improvements adopted. The financial pressures experienced by transport organisations in recent decades are producing tightly defined and restricted processes for developing and managing projects. These restrictions are aimed at creating competitive situations in which proposals from different service providers can be assessed and compared objectively. While the process works well in a technologically mature environment, it can hinder the introduction of major innovations.

The individual components in most transport engineering systems have been highly optimised as a result of continued financial pressures from the client organisations and competition between the service providers. It is now reaching a point where the most likely way in which major improvements are going to be achieved in the future is by re-engineering total systems; that is, by starting with a clean slate and developing completely new ways of undertaking projects. Re-engineering changes the boundaries between planning, design and construction; responsibilities for various tasks change; whole stages in the project process can be eliminated and feedback loops introduced, where none existed previously; and it can change the relative costs of the remaining stages. Further, major innovations create a monopoly situation until competitors can catch up, and the client has to deal with one service provider it if wishes to capture the benefits immediately. In brief, it conflicts with just about all the control mechanisms established to ensure that the existing system operates efficiently and economically.

This paper addresses the scope and the magnitude of the problem and looks at various ways of resolving the conflict.

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## Introduction

> *If a man makes a better mouse trap than his neighbour, tho' he builds his house in the woods, the world will make a beaten path to his door*
>
> Ralph Waldo Emerson

Unfortunately Emerson was guilty of making a statement so wildly wrong that it is a classic. Almost every new product encounters many barriers when the developer seeks to take it to market, and this paper seeks to look beyond particular innovations in transportation engineering and address the problems of how to get innovations adopted. The authors' motivation arose from experience with trying to introduce a new software package to a range of transport organisations. Many of the barriers that were encountered were artefacts of the interactions between the organisations and people that make up the transport industry and had nothing to do with the product. While the following discussion is couched in terms of a developed product or service for the transport industry, the issue is much wider and applies to all industries. Further, it could easily be rephrased in terms of proposals for contract research.

Organisations which are leading the introduction of technology are organised in very different ways than conventional ones. For example, some Internet-based companies have no head office location to reduce the head office staff. They have realised that technology not only alters the ways that it is possible to work, but enables ways of working that are fully distributed and honour the 'autonomous agent nature of independent intelligence' (McMaster 1997). These organisations are able to create and take advantage of innovative ideas and turn them into profit. This requires agility in action, immediacy in response, global presence, and relentless creation (SRI 1997).

Being in favour of innovation in a research forum is axiomatic, but getting innovations adopted is not straightforward. Despite lip service, innovation in the wider world is not so highly regarded, and the more radical and far reaching the innovation, the greater the difficulty in getting it adopted. Basically most organisations want innovations that will reduce their costs or increase their profits, have a negligible risk of failure, and fit into their current mode of operating with the minimum amount of disruption. Innovations that represent improvements to an existing system or introduce competitive products to an already established category have a relatively straightforward struggle to get established. A new traffic assignment model or CAD package has to displace an existing product, but the market is already established and the developer 'only' has to persuade organisations in the transport industry that they have a superior product and that it is worth the time and trouble to change. This is not an easy task, but it is relatively well defined.

However, when the innovation represents a major re-engineering of the whole process or structure to which it is being applied, the barriers to introduction can be formidable. Re-engineering changes the boundaries between planning, design and construction; it transfers responsibility for various tasks between participants. Whole stages in the project process can be eliminated, and feedback loops introduced where none existed previously; and it can change the relative costs of those stages that remain. These wholesale changes encounter many additional barriers not faced by new products in an established category. It is not reasonable to advocate that wholesale changes should be avoided and innovations restricted to incremental improvements. The individual components in most transport systems are already highly optimised as a result of continued financial pressures from the client organisations and competition between the service providers The industry is now reaching a point where the most likely way in which major improvements are going to be achieved in the near future is by re-engineering total systems; that is, by starting with a clean slate and developing completely new ways of undertaking projects. Incremental improvement can then resume on the new process until a combination of circumstances permits another big leap forward.

## Barriers to innovation

The approaching of a new millennium inspires many organisations to think and act in new ways, yet there are barriers to innovation. Larger and historically successful businesses are not organised to deal with the rapid change and new models demanded by the changes in technology (McMaster 1997). Established organisations, groups of people or individuals tend to resist change. This is not necessarily a bad thing as change for its own sake can be an expensive and pointless exercise. When it happens slowly over a relatively long period of time, change can be described as evolutionary or minor, and usually encounters little, if any, resistance Radical change happens quickly, and the status quo can be upset in a very short period of time The people and organisations involved have to learn new skills and ways of behaving in order to survive. Successful management of change is a key element of the development and diffusion of new technology – whether for a developer/researcher first entering a market or for a well-established organisation innovating to compete.

It can be very difficult to get a new idea adopted by a large number of people, in any field there is a large numbers of known potential products, but relatively few of them make it into widespread use From the time that a technology first becomes available, it can take years for an innovation to be accepted into general use. The barriers to innovation are many but can be divided into three basic categories:

- Technical and financial.
- Institutional.
- Conflicts of interest

### Technical and financial barriers

The technical barriers to introducing innovations address questions such as: Does it work (well)? Does it make financial sense? These are probably the most straightforward barriers to deal with, and the most logical. While all innovators would tend to respond in the affirmative to both questions with regard to their particular contribution, it is necessary to be realistic and recognise that many innovations do not scale up well. A method which works on small-scale projects used to test a concept in the laboratory may not work so efficiently in the field – computing time may increase exponentially, or enabling technologies necessary for large-scale application may not be available readily or may be too expensive.

In established markets, the technical question of whether a new product works can be answered by applying a series of tests developed over years, and based on experience with existing products. For example, the developer of a new CAD package can be asked to demonstrate how well it can recreate specific test models of roadworks and interchanges, and the ease of use can be compared with existing packages.

The answer to the question of whether adopting a new product or service makes economic sense is a matter of judgment based on assessments of a number of issues, e.g.:

- Whether the additional features are worth the cost and difficulties of switching systems Changing the existing way of operating always carries a cost in discovering how to use the new system or product most effectively, and training operating staff who may not wish to learn. These costs often exceed the direct financial cost of purchasing or licensing the new product. Unless the benefits are sufficiently great, the costs associated with overcoming existing momentum may be overwhelming.
- The likelihood that the new supplier and product will survive in a competitive market. If they cannot survive then the time and money invested in purchasing the new product and in training their staff to make best use of it is lost. Further, the client organisation incurs further costs in replacing the new product and retraining their staff. A service is in a slightly different position as it can be viable on a one-off basis, and failure of the supplier to survive after the completion of a specific project may not be important.
- Whether the manufacturer of their current system will introduce similar features in the near future. No participant in a competitive market can afford to stand still, and any new feature introduced by a competitor that represents a significant enhancement is certain to be copied. The main question is how long will it take.

When looking at innovations that seek to re-engineer some transport system process, additional questions arise such as: Is it possible?, What can be expected of it?, Does it solve the right problem? We have managed without it in the past; why do we need it now?

The first question can be hard to answer to the satisfaction of the potential client, particularly if the client or their staff have been involved in unsuccessful attempts to develop a similar product in the past. The second is even more difficult as it is essential that the client understands the answer, rather than thinks they understand the answer. Misunderstandings concerning the purpose of completely new developments can present enormous technical barriers, and lead to unjustified complaints that it does not work properly. To many people, if software looks like a CAD package it should operate like a CAD package and provide the same functionality. (A screwdriver looks like a chisel, particularly to someone who has not seen one before, but has a totally different function.)

The third question is not one that the client organisation asks so much as answers, and arises because the many problems or challenges in transport engineering (and other disciplines) are often incompletely specified. This can be a real trap for researchers or developers, and occurs because people tend to concentrate on those parts of a job that they think are the most technically difficult and regard many of the other crucial elements as being understood. As a consequence, in the absence of earlier successful solutions to serve as an example, the target problem which the researcher or developer adopts as the focus for their work may be the wrong one. This is often not obvious until the (nearly) completed work is presented to the client who points out its deficiencies For example, in the course of our work to develop software to optimise the alignment of roads or railways to minimise costs, we discovered that the problem we were addressing was quasi-qualitative rather than pure quantitative; costs had to be balanced against qualitative aspects of the alignment. (However, because of the difficulty of automating the quantitative optimisation, all the work we could find in the literature concentrated solely on the quantitative aspects.) Consequently, producing just the globally minimum cost alignment would not constitute a useful solution, and the problem had to be redefined to one of producing a range of low-cost solutions with different qualitative properties, to enable planners to exercise their judgment on a range of options.

The last question is a justifiable demand that anything totally new should be able to warrant its introduction, although too often it is used as a means of resisting change.

Institutional barriers

Many institutional barriers to innovation are a consequence of an organisation's need to ensure its survival. Organisations, whether government or private, do not exist for the benefit of researchers, but have their own objectives and constraints, and any changes to the status quo must be justified on the basis of potential benefits and costs in the event of success or failure, and the level of risk.

The introduction of new technology potentially involves three major parties – the developer, the client and the consultant – each of whom has a different perspective.

*The client:* The financial pressures experienced by the transport authorities in recent decades are producing tightly controlled (restricted) processes for developing and managing projects. These controls are intended to create competitive situations in which proposals from different consultants or contractors can be assessed and compared objectively. While the processes work well in a technologically mature environment, they can prevent the introduction of major innovations that can provide major benefits.

The individual components in most engineering systems have been highly optimised as a result of continued financial pressures from the client organisations and competition between the service providers. It is now reaching a point where major improvements can only be achieved by re-engineering total systems; that is, by starting with a clean slate and developing completely new ways of undertaking projects. Re-engineering changes the boundaries between planning, design and construction; responsibilities for various tasks change; whole stages in the project process can be eliminated and feedback loops introduced, where none existed previously; and it can change the relative costs of the remaining stages. Further, major innovations create a monopoly situation until competitors can catch up, and the client has to deal with one service provider if it wishes to capture the benefits immediately. In brief, it conflicts with just about all the control mechanisms established to ensure that the existing system operates efficiently and economically.

*The developer:* The development of new technology involves some consulting to provide the field experience necessary to finetune the technology to the needs of the client organisations, to familiarise potential users with the benefits to be gained from the technology, and to cover early costs. However, the developers are not consultants in the long term, they gain their main income from selling or licensing their technology to others. As a consequence they cannot provide the same range of services as a regular consultant. This means they cannot compete for standard projects on their own, but need to work with the end client and the normal consultant in a special relationship.

*The consultant:* Consulting firms can have as much difficulty with technological innovation as the developer and the client. They cannot afford to 'bet the company' on untested technology and need to adopt a cautious approach to innovations. As a consequence, they seek to minimise the risk by asking the developer to provide an extensive list of satisfied clients; while at the same time seeking exclusive access to products that may give them a market advantage.

A consultant contemplating the introduction of new technology that reduces the final cost of constructing a road, needs to consider whether additional costs incurred in his stage of the project will make his proposal uncompetitive. Further, it is not unknown for technology that will benefit the client to result in a reduction in the consultant's profit; particularly in early applications, when the consultant has to engage the researcher, who developed the system, as a subcontractor and purchase novel data sets. So unless consultants think they need to use the new technology to obtain the job, it is not in their interests to take the initiative.

## Conflicts of interest

Conflicts of interest can occur at both the organisational and personal levels, and arise because the entities that bear the cost or risk of innovation are not necessarily those that are likely to gain the benefits.

*Organisational:* With the rise of outsourcing in recent decades, the potential for conflicts of interest has risen steeply, particularly for consultants. It is not uncommon for technology that will benefit the client to result in a reduction in the consultant's profit. Further, if the consultant has to sell the concept of the technology to the client as well as their own capabilities to undertake the work, they may decrease their chance of winning the contract. Thus, while the client may benefit, a major portion of the cost and the risk of proposing or introducing the technology would be borne by the consultant.

*Personal:* The personal conflicts of interest relate to individuals in the organisation into which the developer is trying to introduce his or her work. They do not deal with the personalities of individuals, but rather with professional challenges. Most people are happy to consider innovations provided they do not complicate their life nor threaten their area of expertise. Research workers are somewhat different from most of the population, including other professionals, in that they work in an environment where the pace of innovation is much faster than elsewhere, and they have to be constantly on the look out for new methods or technologies that they can employ.

The classical example of a conflict of interest at the personal level is the introduction of word-processing packages on PCs during the 1980s. These presented a major challenge to secretaries and typists, because it meant they had to learn a completely new set of skills and much of their existing expertise became redundant. Many of the short-term costs and inconveniences were being experienced by individuals, but the benefits were reaped by their employers. Consequently, despite any technical advantages, most typists at the beginning of the era were reluctant to adopt word processing because of the complications they introduced to their work life. In the longer term, it eventuated that those individuals who did not actively try to adapt disappeared from the workforce, as the new technology required fewer people; however most individuals do not look that far ahead.

Professionals are not immune to such situations, and are probably much better at identifying them, although they may not describe them so explicitly. A simple example in this instance is the 'General Motors' model for car following. The original model proposed in the 1950s had some very elegant mathematical properties that supported an algebraic relationship between microscopic and macroscopic flow conditions. Unfortunately, it did not fit the data very well and was modified several times to improve the fit. The modern descendants no longer possess the neat algebraic relationship between microscopic and macroscopic flow conditions and the model parameters are difficult to estimate, but because so many traffic engineers have developed expertise with this model while building their careers, they are resistant to developing or accepting totally new models.

When the innovation is so radical that it involves re-engineering the entire process, even individuals who are relatively senior in the organisation and no longer involved with day-to-day technical work, but who owe their status to their understanding of the current system and the way it operates, may be uneasy. While very few professionals would consciously base their recommendations or decisions on potential threats to their position arising from new technology, the nebulous menace may well bias their judgment. Further, the unfinished or unpolished nature of most innovations, when they are first presented to potential users, provides plenty of 'valid' reasons for not adopting the technology.

## Overcoming barriers

All three participants in the innovation game can play a role in overcoming the barriers.

### The client

Innovation is not important for its own sake, but for the improvements in cost, increases in efficiency and competitive advantage that it can deliver. The benefits of innovation were neatly summed up in a recent Whitehouse Paper, *Science and Technology Shaping the Twenty – First Century* (OSTP 1997), submitted to the USA Congress which declared

> *Technology is the single most important determining factor in sustained economic growth, estimated to account for as much as half the nation's growth over the past 50 years....In today's highly competitive global marketplace, technological leadership often means the difference between success and failure for companies and countries alike*

n today's environment all organisations have competitors. The competitors faced by a state overnment road or rail authority, may be the equivalent organisations in other states that are competing for a large share of Federal funds; or possibly non-transport organisations in the same state that are arguing that they can make better use of the funds. Consequently it is important for any transport organisation to maintain an active search for new technologies that will assist deliver better value for money.

Of the three participants, the client has the most to gain by the successful introduction of new technology, and the power to remove many of the barriers to innovation. The client sets the rules for competition between consultants for contracts to provide specific services. Those rules are designed to produce the optimum result in the application of mature technologies, and as a consequence, tend to exclude process re-engineering, and discourage early adoption of new radical technologies. (In fact they can kill off new technologies before they have a chance to prove themselves.) The best solution is to develop a strategy for identifying and testing new technologies without prejudicing the normal competitive tendering process for routine work.

It is not possible for all organisations to be early adopters of new technology, nor is it desirable that all client organisations attempt radical innovation simultaneously. Innovation carries risks as well as benefits, and unless an organisation is equipped to assess and manage those risks, the results can be catastrophic. The risks can be minimised by establishing processes to actively identify, test and adopt new technology. Identifying new technology requires maintaining an overview of broad research developments and taking an active role in seeking potentially useful technologies. The emphasis on active is important because it means that the organisation develops its own assessment of the most promising developments rather than relying on that information which the developers choose to supply. It means that the organisation buys technology rather than is sold it, and is more likely to end up with the right technology, and to get it early rather than late.

There are several phases in the adoption of new technology:

- The so-called 'bleeding edge' which combines high risk and high potential gain. There are still a lot of unknowns at this stage particularly with regard to scaling up, even though the underlying technology may look solid. Even an organisation that actively seeks potentially useful technologies should not seek to lead the field in all areas. Costs and risks need to be balanced against likelihood of very large gains if the project proves successful. The best policy is to restrict bleeding edge involvement to promising advances in the core business area.
- Early adoption in which organisations reduce the risk by waiting to see which new technologies appear to work well in similar organisations and then moving rapidly to adopt the successes. There is still an element of risk as the technology may not yet have stabilised, but observing the mistakes of others can assist in reducing the risks, and they can still gain substantial advantages over most of their competitors.
- Moving with the flow as the bulk of the field decides that the 'new' technology is sufficiently stable and risk free to justify its adoption.
- Late adoption by organisations that are frequently averse to change and may have delayed it until they would be isolated if they failed to move; at this stage the issue of adoption can become a matter of survival.

## The developer

The developer needs to identify the real client and determine their desires and needs

Identifying the client can be complicated as in any situation there can be more than one interested party that needs to be satisfied. Potential clients include the organisation that the developer is trying interest, the organisation's technical professionals, its financial managers or even the lending institution that is financing the project. In a large private infrastructure project, the institution providing the funding can have a larger stake in the project than the 'owner' of the infrastructure, and in the interests of being repaid may want to improve the financial viability of the project by ensuring that the tools used by the project developer are the best available.

Determining the desires and needs of the client is an essential part of the process and it is essential to recognise that the two are frequently different. The client usually wants to do what they are already doing in a more efficient manner, or more easily, or more cheaply, etc.; but they often confuse methods they currently use with their goal This is not particularly surprising as familiarity with how a goal is currently achieved can blind individuals and organisations as to how it might be achieved. It is often easier for an outsider with less familiarity and a more remote perspective to spot opportunities for changes to the structure of the process An historical example concerns a road organisation that was interested in changes in peak-period traffic, and sought advice on how to process the detector data from their computerised traffic signals to produce the AADT (annual average daily traffic). They then proposed to estimate peak-hour flows by applying an empirical factor to the AADT. It took several meetings with the organisation to persuade them that using the detector data directly provided much more detailed information about the duration and intensity of peak-period traffic than they could possibly get by using AADT

## The consultant

Consultants also have a stake in innovation. They are in the business of marketing their expertise to (potential) clients, and that expertise may include familiarity with new technologies and methods that could provide substantial benefits to the client. In these circumstances, it is an advantage to be an early participant and gain experience that can be marketed to other clients (if the new technology changes the status quo) However, a major reason for a client to engage a consultant is to avoid making expensive mistakes, and a consultant who takes the initiative and recommends the use of a new technology that fails to perform, may be considered to have made a mistake. This dilemma is similar to that faced by the client, and the solution is similar.

It is not possible for all consultants to be early promoters of new technology, nor is it desirable that they recommend a radical innovation to all their clients before they have obtained some practical experience. The risks associated with the technology can be minimised by understanding the maturity of the development and the chances of success, through a monitoring program similar to that suggested for clients Further, any consultant recommending a new technology needs to be familiar with their client, as some organisations will be better able to handle innovation than others. The client organisation needs to recognise and accept the risks as well as the benefits, which requires that the consultant limit initiating trials of new technologies to clients that understand the nature of innovation. In the event that the new technology fails to perform with such a client, the cost is borne by the client and the 'blame' by the developer/researcher. If the consultant suggests trials to an insufficiently cognisant client, the consultant is likely to take a large proportion of the blame for any failures. However, if the consultant monitors new technologies closely, makes balanced assessments and selects the clients for any trials carefully, the benefits to all parties can be substantial.

## Conclusions

The rapid development of information technologies and the global expansion of markets have forced organisations to shape their future through re-engineering that involves fundamental rethinking, radical realignment of the business processes and re-rationalise resources. Re-engineering is more than technology, it changes the boundaries between planning, design and construction; responsibilities for various tasks change; whole stages in the project process can be eliminated and feedback loops introduced, where none existed previously; and it can change the relative costs of the remaining stages

The financial pressures experienced by the transport organisations in recent decades are producing tightly defined and restricted processes for developing and managing projects. As a result, the individual components in most transport engineering systems have been highly optimised. It is now reaching a point where the most likely way in which major improvements are going to be achieved in the future is by re-engineering total systems. However, established organisations, groups of people or individuals tend to resist change and innovation. The barriers to innovation can be divided into three basic categories: technical and financial, institutional and conflicts of interest. While in overcoming the barriers, there are three participants involved in the innovation game: the client, the developer and the consultant. Among these three players, the client has the most to gain by the successful introduction of new technology, and the power to remove many of the barriers to innovation. The client sets the rules for competition between consultants for contracts to provide specific services. Innovation carries risks as well as benefits, and the risks can be minimised by establishing processes to actively identify, test and adopt new technologies without prejudicing the normal competitive tendering process for routine work.

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