Delivering railway projects using systems engineering

Bruce Elliott and Ambrose Langley-Poole

The problem

Someone wrote that 'change is the only constant'. This is the sort of statement that some would deride as insightful yet unhelpful while others regard it as a life-changing mantra. To those of us working in the rail industry however, it is a very real, present and serious issue.

Ours is an industry which has seen tremendous upheaval over the last decade, beginning with preparation for privatisation and set to continue for some time to come. With another government-led restructuring on the horizon, some are beginning to wonder when there will ever be a period of stability when we can focus on the core tasks of delivering a safe, effective and efficient rail service. There may never be one and this poses difficult challenges for programme managers.

Outsiders have difficulty in understanding what is so complicated about running trains on tracks on time. After all, you don't even have to steer them so it should be simpler than road transport. But it's not that simple. The industry manages and operates infrastructure components with an operating life of between 30 and 50 years, derived originally from over 25 privately-owned pre-British Rail competitors. The result is an asset base with a staggering diversity of infrastructure and rolling stock designs which pose difficult inter-operability, renewal and enhancement problems. So changes don't happen quickly, can be very expensive and have significant long term consequences.

Yet the industry must press ahead with improving the service which the public needs, expects and has paid for. The answer may not just lie in trying to solve the big problems, but also in blending the pragmatic principles of systems engineering with programme and project management basics to bridge the challenges posed by organisational fragmentation and technical diversity.

Lines of attack

Although railway projects sometimes suffer from problems that fall wholly within a single specialism, the really difficult and expensive problems tend to be systems problems; those that involve the interactions between sub-systems (and therefore involve more than one technical discipline).

Systems engineering and systems integration are the names used to describe a systematic approach to co-ordinating the development of sub-systems in order to deliver what the customer wants. Although Atkins and other parts of the railway industry prefer the term systems integration, we use the term systems engineering in this article as it is more widely used outside the rail industry.

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Atkins Rail is the largest UK-based international railway consultancy and is a truly multi-disciplinary company, employing some 1,400 staff with extensive specialist experience across the engineering and non-engineering railway disciplines.

Systems engineering aims to prevent systems problems before they occur. And although this sort of technical coordination has always happened throughout the railway's 200-odd year history, it is only in the last 25 years or so that it has been given a name and studied in its own right.

Some people like to debate whether systems engineering should be seen as a branch of engineering or of

project management. We try to avoid getting sucked into this infertile debate. Systems engineering draws on both disciplines and adds some ideas of its own. We want to make best use of these ideas. We are not concerned whether the systems engineering is done by someone who calls themselves a project manager, a systems engineer, a mechanical engineer or anything else. We are just concerned to see it done well.

Systems engineering

Systems engineering is the child of necessity, born in the 1950s and 1960s out of the need to get ever more complex military, aerospace and telecommunications systems to work.

Today there is an International Council on Systems Engineering (INCOSE) and a range of systems engineering handbooks and standards. Typical activities called for by these standards are:

- establishing a thorough and precise statement of the technical requirements for the system that has to be built or changed
- carrying out analyses into the trade-offs between different ways of delivering these requirements
- deriving technical requirements for sub-systems which can combine to deliver the top-level requirements
- defining precisely the interfaces between the top-level system and the rest of the world and between the sub-systems
- operating change control processes to ensure that change proposals are properly thought through before being accepted and keeping the requirements and interface descriptions up-to-date as things change
- reviewing and responding to technical issues as they emerge

Exploiting systems engineering in the rail industry

Many existing systems engineering standards have been developed in the military, aerospace, nuclear, air traffic management and telecommunications sectors where there is a proven track record of effective application. One obvious approach could be for the rail industry simply to apply one of these standards. We have seen this attempted but so far without great success. We suggest two reasons for this.

A railway project is not like a space project. We hardly ever build truly new, stand-alone rail systems. The top-level system for us is the railway network, so all our projects have to be seen as modifying a system that already exists. The fundamental issues may be the same for a craft to land on Mars as a new train but the balance is different.

The concern for the space team is to achieve the mission objectives at all. The general objectives for the train, principally to run at such-and-such a speed, have probably already been achieved several times. The challenge for the rail team is to achieve the objectives within the constraints imposed by the existing railway. The rail approach needs a different balance from the one applied to space projects, if it is to be effective.

There may be room for improvement but rail does have useful existing systems engineering practice that works. The first law of engineering ("If it ain't broke, don't fix it") obliges us not to throw this practice away but, instead, to build on it.

Our approach

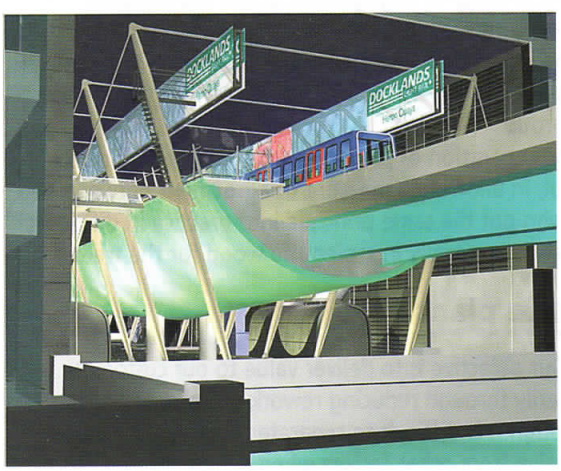
Atkins Rail is the largest UK-based international railway consultancy and is a truly multi-disciplinary company, employing some 1,400 staff with extensive specialist experience across the engineering and non-engineering railway disciplines. We recognised the need to develop its capability in systems engineering several years ago and set up a formal initiative to achieve this in September 2002. Our approach has been as follows:

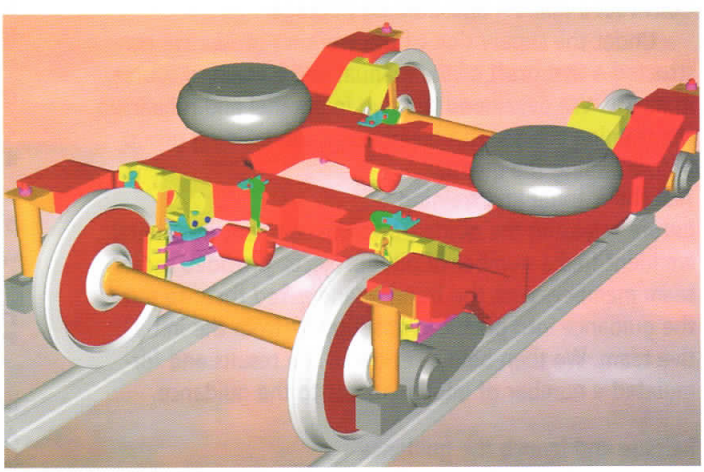
Engage senior management

We set up a director-level steering group in May 2003 with a remit to provide assurance that the initiative met the business needs of the various strands of the business.

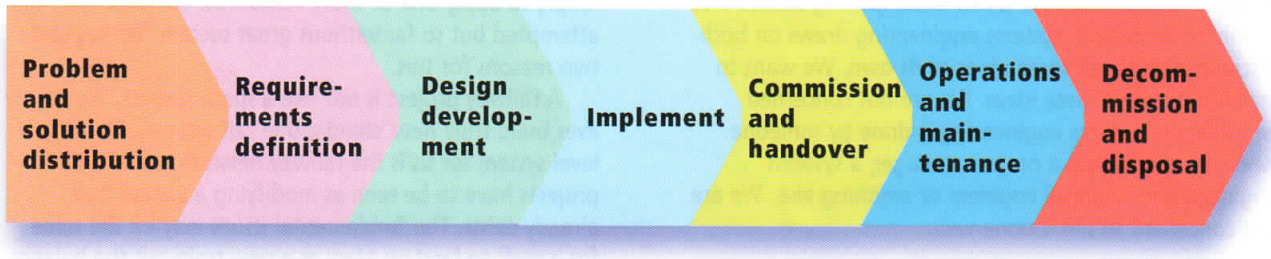
Engage practitioners

The directors of each of the functional units nominated one or two senior engineers, project managers or other specialists to join a working group. The group first





Modern design tools assist with modelling systgem interfaces, such as in modern station design, as at Heron Quays on the DLR (above left) and at the 'wheel/rail interface' where trains meet tracks.



met in June 2003 with a remit to review the deliverables of the initiative and check that they were technically sound in the context of Atkins Rail's business. Over time the working group's focus has moved outward to acting as champions for the initiative and communicating, in both directions, with the wider company.

Establish framework

We carried out a review of authoritative references on systems engineering and used this to formulate a systems lifecycle and number of fundamental systems engineering principles. The systems lifecycle should not be confused with a project lifecycle; it is a model of the phases that a system passes through which typically will involve more than one project. We deliberately used a simple lifecycle, which had been proved to be applicable to several railway disciplines as illustrated above.

The system lifecycle – survey best practice

We looked again at published work on systems engineering and cross referenced examples of best practice to our framework. We also carried out a survey of best practice within Atkins, talking to individuals who had been involved in well-regarded and successful projects and mapped their experience onto the model.

Close liaison with project management process owners

We met regularly with the owners of the company's project management processes to make sure that the two were fully integrated so that Atkins Rail's staff see them only as complementary aspects of one integrated business management system.

Construct a manual and training package

Under the supervision of the working group, we constructed a first draft of the manual and a training course in its use. We developed the two in parallel and rehearsed the training course with members of the training group before issuing the manual.

Test the manual and training

Before releasing the guidance to the company in general, we identified a number of pilot projects, provided senior team members with the training and asked them to put the guidance into practice with support from the initiative team. We then held a review of the results and formulated a number of improvements to the guidance.

Reissue and launch the guidance

We updated the manual and training, formally incorporated the guidance within the company's business management system and carried out a major communications exercise.

Plan for support, feedback and change

Working group members actively supported the users as the guidance was taken up. Users were encouraged to provide feedback by paper, 'phone or email and a change control process was established.

Progress to date

By mid-July 2004, the guidance had been applied to five pilot projects and one pilot sales proposal. The projects vary in size by more than two orders of magnitude and cover both the metro and mainline railway market, reflecting the diversity of Atkins Rail's business. Briefings on the new guidance had been delivered at more than a dozen Atkins Rail offices across the UK and 77 of our staff had attended a two-day training course supporting the guidance.

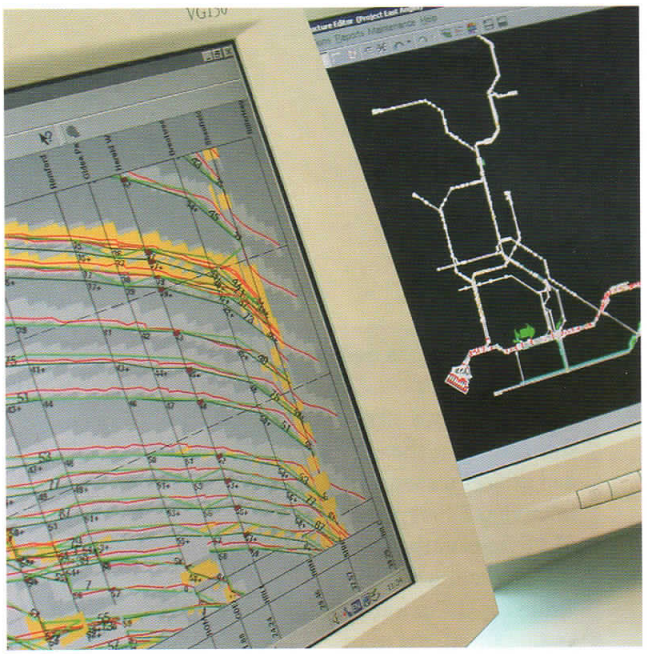
The guidance had been incorporated into our overall business management system, 42 change proposals had been raised against the guidance and the majority implemented.

For the moment, our evaluation of the benefits is based upon the collective judgment of the steering group, working group, initiative team, pilot project teams and training recipients. There is consensus on some general conclusions:

1. The guidance is sound at the principle level. The change proposals mentioned above have driven some very valuable improvement in the detailed guidance while leaving the principles largely unchanged.
2. Review of past projects convinced us that putting these principles into practice has the potential to yield significant overall savings in project costs.
3. The strategy of engagement across the company is correct and, indeed, quite essential. One of the side-benefits of the initiative that we have seen to date is some useful cross-fertilisation of ideas between members of the working group.
4. The separation of principles from detailed guidance is useful, in allowing a measure of agreement between people who put the same principle into practice in different ways and generally in seeing the wood for the trees.

Future plans

Our objective is to deliver value to our customers primarily through reducing rework on railway projects. Although it is difficult to separate the effects of the initiative from other factors when evaluating the outturn on a project, we have a programme of data collection underway which should in due course allow us to make an intelligent estimate of the contribution that the



Complex modelling tools are used to design timetables which have to account for the need to run a mix of train services on a common infrastructure.

Running some of the most modern trains in the world, such as the Gatwick Express (above) on some of the oldest infrastructure poses some difficult challenges.

initiative has made to our business and our customers' businesses.

Experience suggests that a decade is the sort of time-frame needed to make sustainable, meaningful change in working practice across an industry. It should be quicker within one company but we have a time-frame of five years in mind for the initiative which is to say, that, although we are starting to see some benefits now, we expect to have to persevere for another two to three years to see the full impact.

We continue our policy of planning in phases of six to nine months so that we can take proper stock of experience to-date and adjust our plans accordingly. The next phase will see:

- continued training with the aim of covering more than 10 per cent of our UK technical workforce and making a grounding in systems engineering part of our basic graduate training
- a shift of focus outward – sharing our work with out customers and partners with the aim of improving it to fit better with their processes and meet their needs better
- a further reissue of the guidance, responding to field experience

Buildability is a key concern when considering multi-disciplinary designs, such as the award-winning Proof House Junction project.

Conclusions

We are convinced that incorporating systems engineering into our project management methodologies will allow us to deliver better railway projects for our customers. We are also convinced that our approach to improving our systems engineering capability is the right one.

At the heart of the initiative has been the establishment of a number of systems engineering principles within a systems lifecycle. This has provided an invaluable framework within which we have been able to merge best rail systems engineering practice with best practice from other sectors and package the results in a usable way, while retaining the flexibility to adapt our approach to the wide range of projects that we encounter and to continue to learn and improve.