Application of System Engineering Techniques to Optimise Benefits of Fixed Speed Cameras

Tom Donnelly[1] (Presenter); Tenix Solutions Pty Ltd

Biography

Tom Donnelly has over 20 years experience in System Engineering on major defence contracts. He holds a BSc in Physics and MSc in Sonar and Signal Processing. He has experience in all aspects of system design and project lifecycle ranging from feasibility study to operational evaluation. He has also managed software development on major projects. For the past 3 years Tom has been involved in the development of road safety technology. He is currently Manager New Technologies for Tenix Solutions. Tom is a committee member of the Victorian branch of the Systems Engineering Society of Australia.

Abstract

The CityLink tollway uses two tunnels, each of which is several kilometres in length, to divert traffic away from Melbourne city centre. In order to provide a safe environment there needed to be a means of enforcing appropriate driver behaviour. Automated enforcement technology was needed because the limited width of the tunnels precludes the use of traditional policing techniques. The challenge was to design and implement a safety camera system which would improve road user behaviour while also providing high levels of performance and reliability in an environment where there is minimal access to operational equipment.

The required outcomes were defined by the State of Victoria, and Tenix Solutions assumed the complete financial and technical risk of developing and implementing a solution under the auspices of their service contract. The project was structured into two stages, a pilot programme and a roll-out phase. During the pilot programme an evaluation was made of two potential solutions, both of which were designed and installed into the Domain tunnel, the shorter of the two tunnels (1.6km). The selected system was further evaluated and characterised leading to initial live deployment in April 2001. Monash University Accident Research Centre (MUARC) were contracted to conduct a detailed study of driver behaviour as part of the pilot programme demonstrating that vehicle speeds were significantly reduced.

Following successful implementation of the pilot system, the rollout programme commenced in the Burnley tunnel in December 2001. The design process used for this project was derived from a system engineering methodology with an emphasis on management of risks throughout the project lifecycle and stakeholder involvement at all major decision points. This paper presents results showing the trade-offs between major system design parameters in delivering the desired levels of overall system effectiveness.

1. BACKGROUND

Road Safety Strategy in Victoria is based on a multi-layered approach ranging from educating the driving public by improvement of road infrastructure through to the enforcement of road regulations. The improvement of the road network in Melbourne through the introduction of the CityLink tollway needed to be balanced out by the provision of speed enforcement capability. In particular the two CityLink tunnels were identified as potential black spots if the enforcement systems were not in place to coincide with the official opening.

Under the terms of the Traffic Camera Office/Enforcement Management Unit (TCO/EMU) contract, Tenix Solutions was contracted to provide the CityLink Speed Cameras as a turnkey solution. Tenix Solutions assumed full operational risk in providing a proactive solution that proved the effectiveness of digital technology while achieving the desired road safety benefit through a reduction in vehicle speeds. The broad requirements of the system were specified by Victoria Police who also defined the operational policy in conjunction with the tunnel operator Transurban.

2. INTRODUCTION

Design of the camera system started during the final stages of the construction of the Domain tunnel which is the shorter of the two tunnels at approx 1.6km. The project was planned to be conducted in two stages with the first stage consisting of two phases. The scope is broadly outlined in the table below.

Project Stage	Scope Definition	Duration	Risk Factor
Stage 1 Phase 1	Feasibility study and overall planning	1 month	Medium
Stage 1 Phase 2a	Project trial and selection of preferred system	3 months	Medium/High
Stage 1 Phase 2b	Type approval and implementation at nominated trial site. Extended evaluation	6 months	High
Stage 2	Installation and roll-out at nominated sites throughout both tunnels	6 months	Low/Medium

Table 1 - Project Scope

3. SYSTEM ENGINEERING METHODOLOGY

The project functional specification required that the system was both effective in the achievement of road safety benefit as well as providing compliance with the detailed technical requirements.
Therefore, there needed to be an optimisation process that provided a balanced solution providing adequate performance in the operating environment and within the operational policy constraints laid down by Victoria Police.

The essence of System Engineering is to achieve an appropriate balance of technical and operational factors leading to an effective system. In practice this tends to require a tailoring of procedures and methodologies to suit the capabilities of the individuals and organizations involved. There is therefore a requirement to provide an appropriate translation of engineering parameters into the broad system objectives that will be understood by the major project stakeholders. The ramifications of this are that project documentation must be couched in appropriate language so that there is adequate transparency of the decision making process.

The approach that was taken on the CityLink Tunnel Camera project was to define the measures of success in terms of measurable outcomes and the testing philosophy required to demonstrate and achieve these outcomes. At the same time the System Engineering philosophy required to achieve these desired outcomes was implemented in accordance with the capabilities of the organizations and teams who were involved with the relevant engineering activities.

Figure 1 below shows the major elements of the System Engineering Process as employed on this project .This is as defined in a number of common Systems Engineering standards (Reference 3) which use a broadly similar approach.

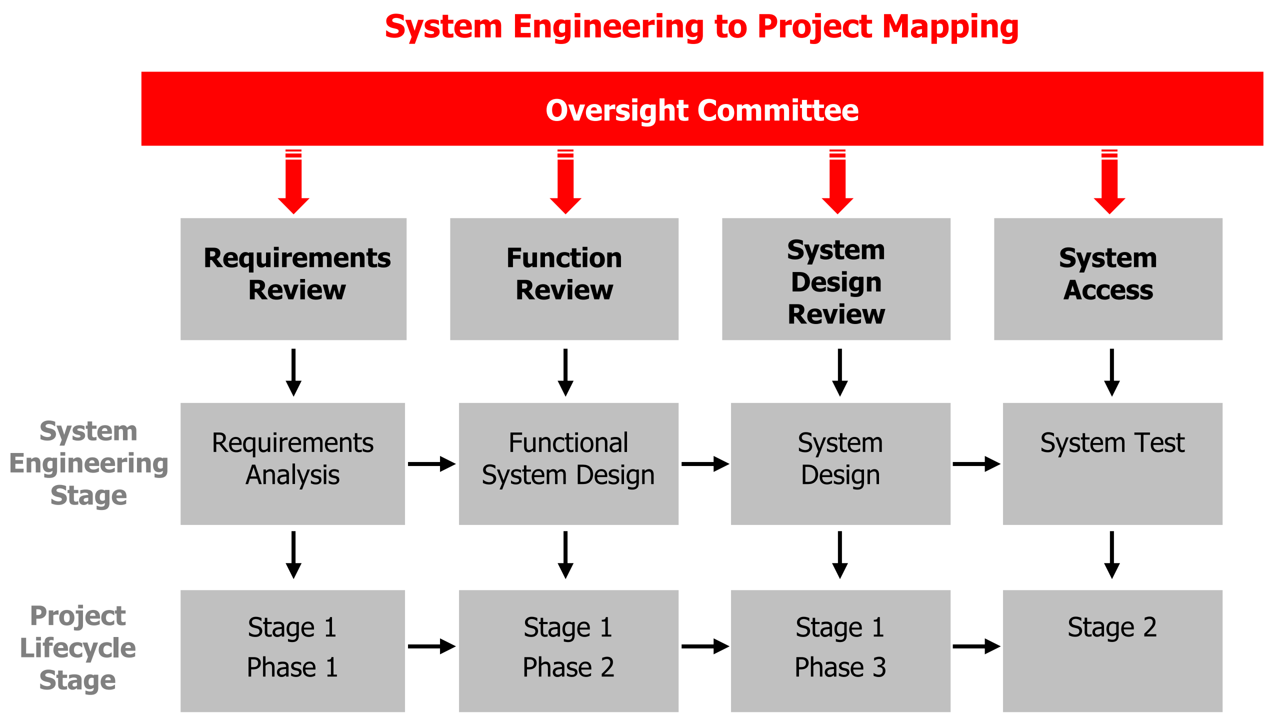

Figure 1 - System Engineering to Project Mapping

4. MEASURES OF EFFECTIVENESS

As stated above, appropriate measures of effectiveness must be defined to guide the delivery of the required operational outcomes. These measures are used to derive a tree of lower level system parameters. These parameters are put together to define the test scenarios. The testing programme is applied throughout each of the phases shown in Table 1 to gauge how the development of the system is progressing.

The two measures of effectiveness that were defined at the outset of the project were the road safety benefit and the broad requirement for system integrity. There is also the implicit requirement to implement the system within the allocated budget constraints.

Road safety benefit has been shown in Reference 1 to be linked to reductions in vehicle speed with a clear relationship between speed reduction and crash statistics. If a reduction in speed can be measured, this can be translated into an expected reduction in fatalities and serious injury crashes. For the purposes of this project, Monash University Accident Research Centre (MUARC) were engaged to conduct a study to measure the impact of the cameras on motorist behaviour.

It was clearly shown at the end of stage 1 of the project that a measurable reduction in speed was achieved. The next step was to design the project rollout through both tunnels to achieve a significant reduction in speed. Additionally, there was a need to make sure that the system provided the desired benefits 365 days per year with no maintenance downtime in the harsh environment of the tunnels. There is no access to the cameras unless the tunnels are partially closed so the system must function effectively with no direct operator intervention.

Additionally, the system must be capable of effective performance against all classes of vehicles and cater for the enforcement of variable speed limits. Prime movers must be photographed from the front and motorcycles from the rear since they have no front number-plate. The above operational requirements lead to the need to define a set of reliability parameters which will allow redundant components to be incorporated into the system design so that failure of any component does not compromise the operation of the camera system.

In the design of the system there is a need to provide maximum possible coverage of the area of interest, while at the same time achieving reliable system operation. For a tunnel camera system the environment is controlled but of relatively low illumination level. The requirement is for a covert mode of operation so that the location of the cameras while known within a broad area is not known precisely to the motorist. This allows a relatively small number of cameras to have the maximum possible sphere of influence.

5. DESIGN METHODOLOGY

The design methodology could perhaps be described as “build a little, test a little”. Thus the objective of Phase 1 was to demonstrate performance capability with the minimum possible outlay. This is important because installation in the tunnel is very expensive due to the very high standards imposed by Transurban for compliance with safety standards.

A stringent review process was developed which attempted to reduce the performance risk to an acceptable level at each phase of the project before proceeding to the next. The review process used a combination of documented evidence from similar installations, engineering review by selected independent experts and prototyping to provide objective proof of compliance with requirements before committing resources. This process allowed the full system lifecycle to be addressed as well as compliance with functional and performance requirements. It should be noted that although subcontractors were not familiar with the review process the principles are sufficiently clear to allow the review process to be effectively performed.

The project management methodology for the project to complement the System Engineering Approach was based on PRINCE 2 (Reference 2). This is geared around the establishment of a Project Steering Group which allows all stakeholders to gain visibility of project status and issues, to which the Project Manager reports on a regular basis. For this project, the committee was termed the Oversight Committee, having representation from Victoria’s Deptartment of Justice, Victoria Police, Melbourne CityLink Authority (MCLA), Transurban, RMIT Innovation and Tenix Solutions.

Reporting to the Oversight Committee were a number of technical sub-committees which were tasked to deal with detailed technical issues and report back to the Oversight Committee for overall direction. These sub-committees dealt with issues such as definition of interface specifications to Transurban infrastructure and Operational policy and guidelines for the then novel automatic digital camera systems.

The major focus of the Oversight Committee was on project schedule with an emphasis on management of technical risk and decision making at the conclusion of each phase to proceed to the next stage of implementation depending on the perceived level of risk. A crucial aspect of the project was to ensure that the camera system was operational when the tunnels were opened to traffic. There was also a need to integrate Victoria Police camera guidelines with the Transurban tunnel safety policy.

Having planned the project from the outset to provide test data at each stage it was possible to provide up to date information on system status through test results that could be easily comprehended by the members of the committee. Also under the Tenix Solutions contract with Department of Justice, the provision of end to end processing services allowed the potential impact of any decisions to be assessed against any possible adverse consequences and the appropriate action taken.

6. OVERVIEW OF IMPLEMENTATION

Having determined the effectiveness of a single bank of cameras, the question then remained of how to install a network of cameras throughout the tunnels to achieve the desired road safety benefit with the minimum deployment of cameras.

The MUARC study indicated that the sphere of influence of speed cameras was of the order of 500 metres. It is considered that this figure would be dependent on the operational policy under which the cameras were operated however it does provide a starting point. The final system configuration needed to take into account the myriad of factors which affect the operational effectiveness. With a working system in place from the pilot programme it is possible to use statistical measures to make decisions about how effective certain configurations will be in practice. Extracting maximum performance from digital cameras requires careful optimisation of parameters. This was facilitated by the ability to process the images through all stages before committing to the final configuration. The final configuration of the cameras provides flexibility in the operation of the cameras as well as coverage of the full extent of the tunnels.

7. SYSTEM OPERATIONS

As stated earlier, the primary measures of success are the ability of the system to promote safer behaviour within the tunnels and to operate efficiently 365 days per year with no downtime. This is also under the proviso that all project-related risk is taken by Tenix Solutions.

The camera systems have been in operation for over 2 years and the reduction in average speeds have been significant. For full details of the reductions in speeds and the expected benefits in serious and fatal accidents see Reference 1.

8. LESSONS LEARNED

Speed cameras need to deliver a significant benefit to the community if they are to be accepted as an essential component of the overall road safety strategy. The design of this project ensured that the delivery of measurable road safety benefits was the primary measure of success. This was backed up by a technical programme which delivered a high degree of system reliability within the budget constraints of the project. This is of course a critical requirement since road safety requires that there is no allowance for maintenance downtime.

The other major factor in the success of the project was the management process applied. This provided visibility of project status and transparency of decision making so that major decisions were taken with a consensus from all stakeholders. This has a major impact on the risk of schedule delays and helps to streamline the testing process since there is a much reduced risk of adverse consequences.

9. CONCLUSIONS

This project has shown that digital camera technology can be used to provide road safety cameras in a difficult environment. The project was completed on time and within budget and has continued to provide effective operation. The major factors in achieving this success were the close involvement of stakeholders and cooperation from the tunnel operators Transurban. In projects of this type, the ability to provide early test data to the key decision makers is crucial. This ensures that key decisions are made with the buy in from all participants. It is also of great benefit to be able to analyse the impact of decisions across the full extent of the processing chain so that decisions are made with the full impact of any changes on the ambit of the system operation.

References

Diamantopoulou, K., and Corben, B.,. (2001), *The impact of speed camera technology on speed limit compliance in the CityLink Domain tunnel:.* Report to LMT, Monash University Accident Research Centre, Melbourne.

PRINCE2 Project Management Methodology. (1997) CCTA. Published under license from Controller HMSO. London UK.

Blanchard, B.S., and W.J. Fabrycky. Systems Engineering and Analysis (2nd edition). Englewood Cliffs: Prentice-Hall 1990.

Acknowledgements

The author gratefully acknowledges the support of Victoria Police (Chief Inspector David Richardson and former Superintendent Bob Wylie), Transurban (Reg Saunders) and Gil Brooks during the project implementation.

Keywords

System Engineering, Road Safety, Project Management, Speed Cameras,