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APPLICATION OF SYSTEM'S ENGINEERING METHODOLOGY TO RAILWAY BUSINESS AND INFRASTRUCTURE PLANNING IN CITYRAIL, SYDNEY AUSTRALIA

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1 BACKGROUND

CityRail is the urban, intercity and provincial passenger rail service provider in Sydney, its suburbs and neighbouring cities of Newcastle and Wollongong. In the early 1990's CityRail increased its focus on becoming a customer orientated business. CityRail began to look at itself as providing transport "products" to meet the needs of its customers, both passengers and Government. CityRail recognised that its product was made up of its people, fleet, infrastructure and collective packaging to deliver its services. CityRail’s Business can be summarised as:

* Providing transport of people
* Market and deliver rail transport services to meet demand
* Offer services where total income at the least meets the total cost.

Business planning workshops identified key success factors, broad action plans and performance indicators.

Of particular importance was the knowledge that a successful business requires both marketing and product delivery. However, the linkage between broad business goals and the system to deliver them was difficult to quantify.

An important step towards bridging this gap and developing suitable supporting infrastructure was in the recognition that the system and the transport services provided deliver a product for customers. This shifted the thinking in emphasis from infrastructure driving the business to business driving the infrastructure. Infrastructure is then viewed as a supporting component of the overall product, recognising also that infrastructure is a large and long term investment with lengthy time frames needed for making changes. The bottom line of the infrastructure planning process is to match the infrastructure to the business.

Following on from this attitude, the second important step was the application of the System's Engineering methodology.

2 SYSTEM’S ENGINEERING APPLICATION TO CORRIDOR PLANNING.

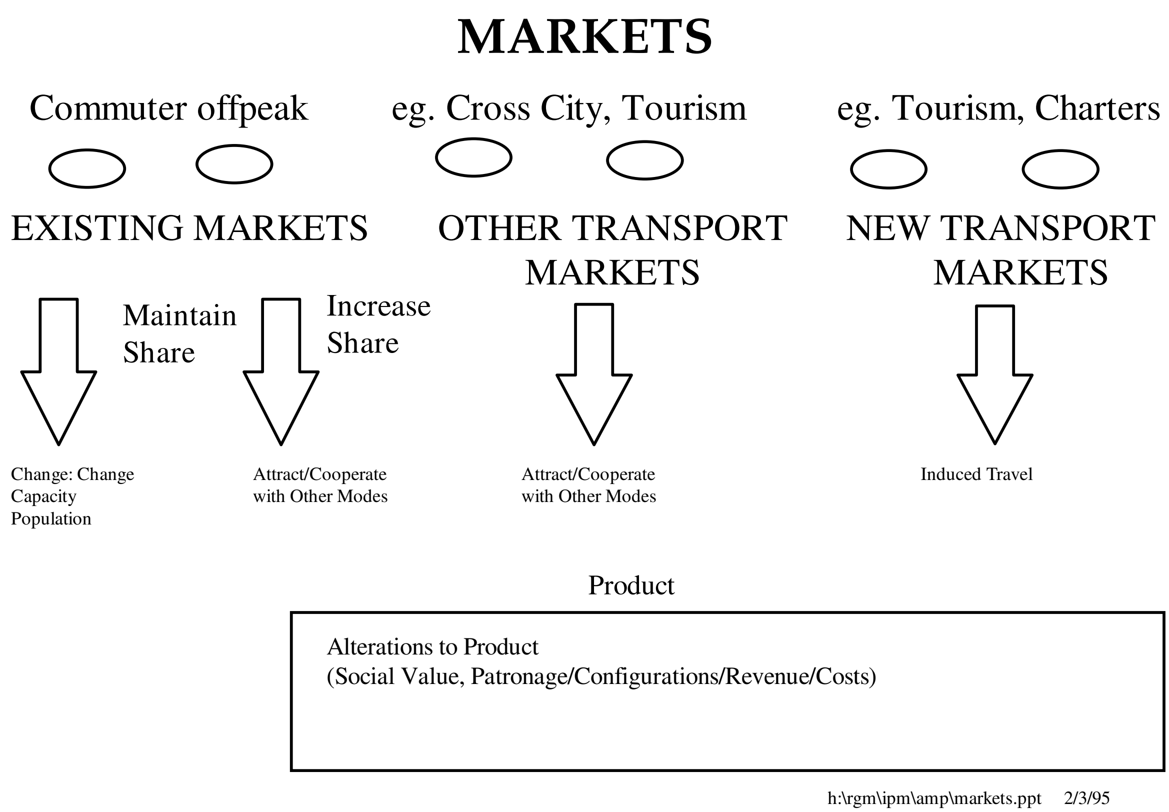
The System's Engineering methodology has developed over the past 30 years in the United States of America’s military and aerospace industries. Traditionally it has been applied at project level for systems such as aircraft, satellite and communications equipment.

In 1994, CityRail piloted this methodology to macrosystem design by applying it to the planning of the complete corridor infrastructure for the Illawarra Division. CityRail's total railway network is approximately 1400 km of which 300 km is in the Illawarra Region.

System’s Engineering, works by firstly identifying the functional and performance requirements a system need to meet to satisfy the mission and then sets about synthesising the system to meet the requirements. It hinges on having good visibility of analysis and traceability of requirements and design baselines, from the aggregate system down into the disaggregrated components of the system. It is characterised by repeating this process of requirements analysis and system synthesis again and again as the design matures.

Applying the System' s Engineering methodology to the complete corridor infrastructure bridged the business to engineering gap by adding up front iterations of the process at the earliest concept design stage of the planning. A key purpose was to assess strategy options, to determine whether there are better ways of delivering the CityRail product.

The process was launched by focusing on the market and product characteristics. The following diagram overviews the market segments; current product focus; the possible target market segments and the considerations when developing an altered product.



The existing market was then partitioned into three broad segments which closely matched current products on offer by CityRail, namely CityMet, Outersuburban and Regional. The corridor was partitioned to match these product segments, each segment having largely its own system and geographical area. Exception was in the CityMet System, which while primarily delivering the urban services also had to deliver the Outersuburban services into their Sydney City destination. Each system had to be designed to also deliver freight services for another operator. Each system was then processed using the System' s Engineering methodology.

The process of defining functional and performance requirements forced the business management to think more precisely about the product requirements to enable them to be separately identified and quantified. Examples of those adopted are shown in extracts from the CityMet System baselines, displayed in the figures 1 to 5.

The system used to deliver the product requirements was categorised into subsystems shown in figure 6.

PRODUCT FUNCTIONS

The CityMet system is the infrastructure and fleet chosen to deliver the CityMet product. The purpose of the CityMet product is to transport people. The following diagrams depict what it is the product is to provide for our customers and what the system is designed to do.

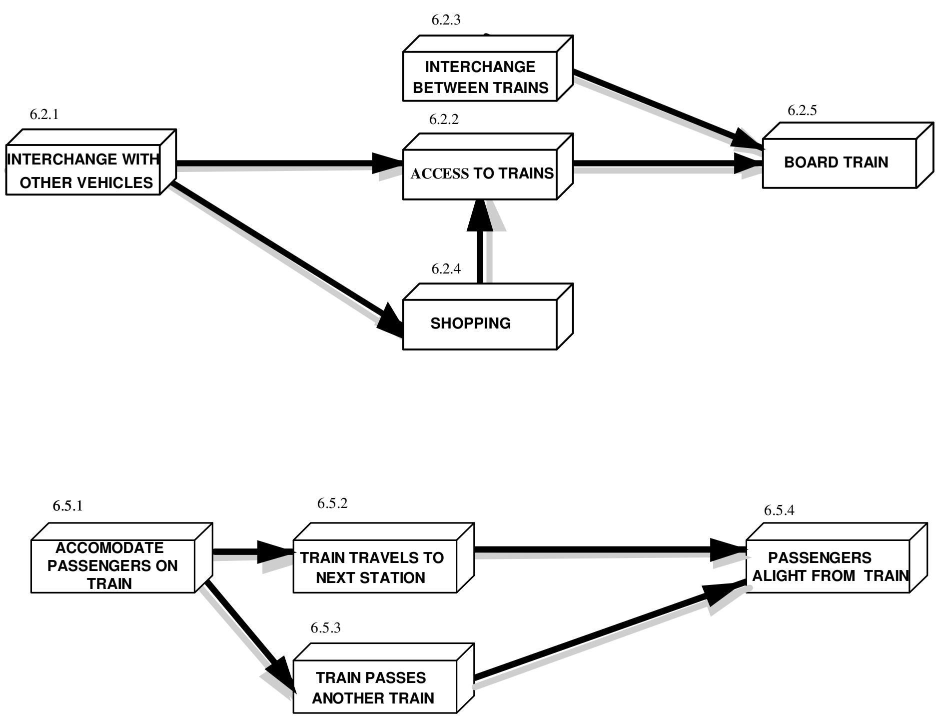
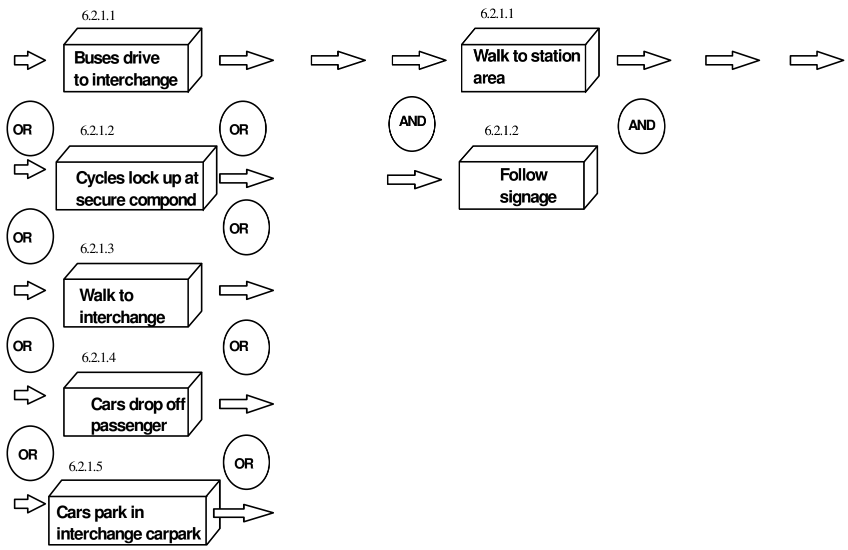


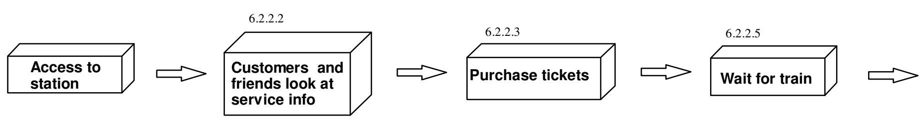
FIGURE 1

A further breakdown of the functions is as follows:

INTERCHANGE WITH OTHER VEHICLES:



ACCESS TO TRAINS:



ACCOMMODATE PASSENGERS ON TRAIN:

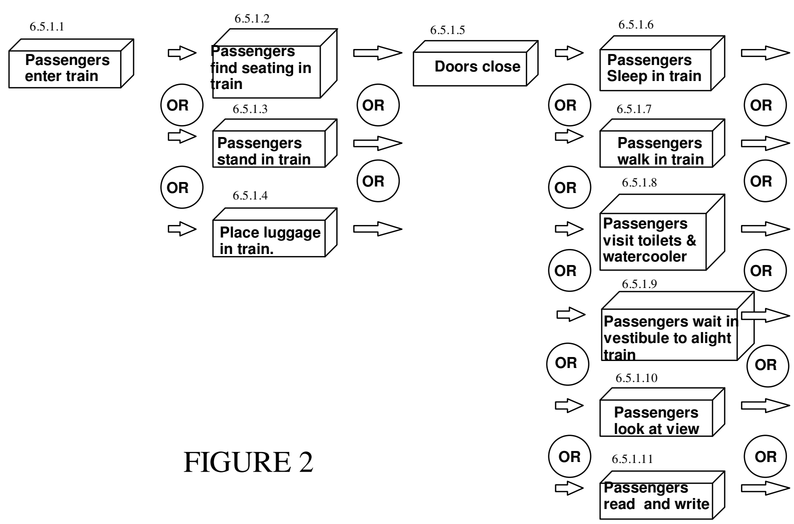


FIGURE 2

TRAIN TRAVELS TO NEXT STATION:

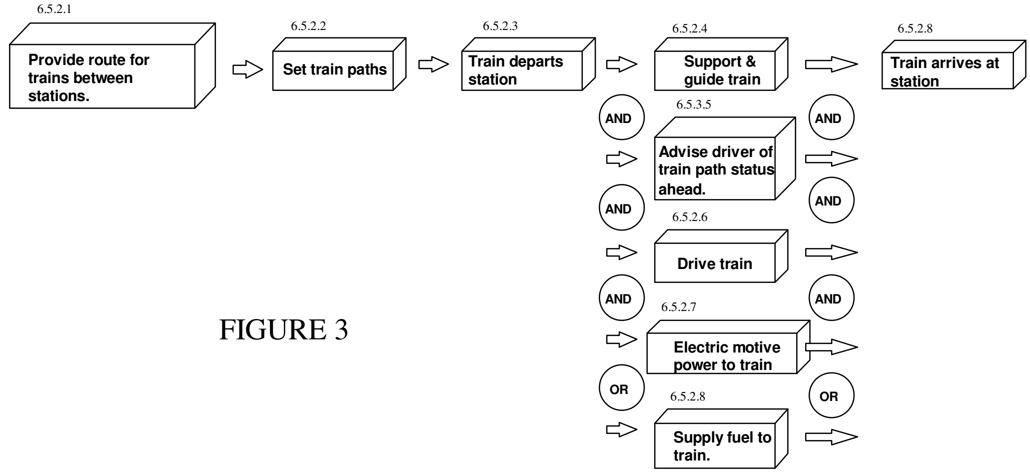
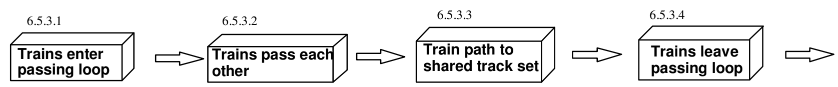


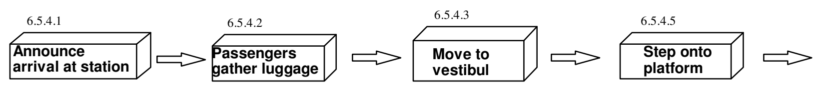
FIGURE 3

TRAIN PASSES ANOTHER TRAIN:



PASSENGERS ALIGHT FROM TRAIN:

FIGURE 4



CITYRAIL PRODUCT REQUIREMENTS

* **Identified in Value Management Studies of Business Segments:**

- Safety
. Collision Risk
. Derailment Risk

- Accessibility
. Intermodal
. Limited Mobility Access

- Availability
. Timetabled Services Run

- Life Cycle Cost
. Total Asset Cost

- Environmental
. Comply with legislation

- Capacity
. Passenger Loading
. Frequency
. Travel Time

- Comfort
. Personal Security
. Train Ride
. At Station
. Cleanliness

- Reliability
. On Time Running
. Intertrain Connections

- Maintenance
. Reliability Centred
. Mechanised

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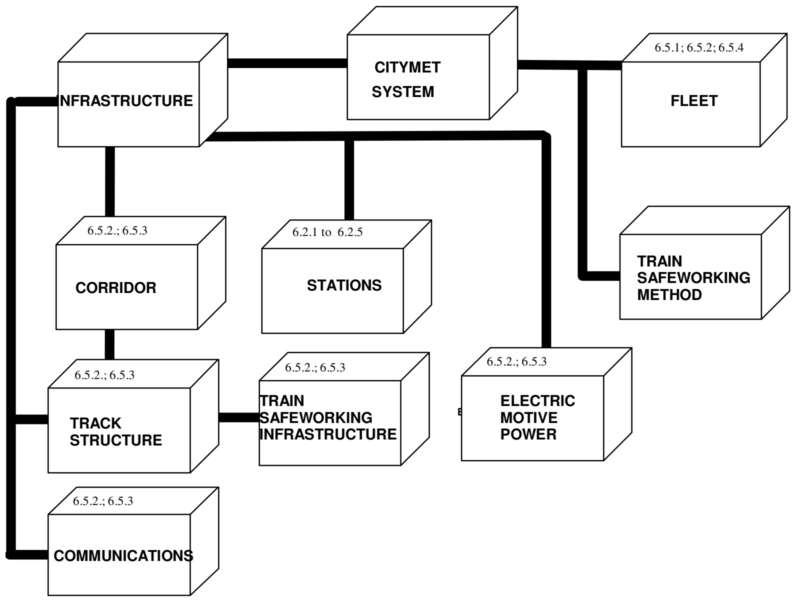
FIGURE 5

THE CITYMET SYSTEM:

The system selected for delivering the product is represented in the following diagram.



The system described consists of:

Physical Elements

• Stations	The customer interface
• Infrastructure	The delivery base
• Fleet	The delivery means

Operating Software

- Safeworking procedures
- Timetables

Human Interfaces

- Customers
- Suppliers
- Employees
- Third Parties (i.e. non-customer public)

FIGURE 6

For performance requirement of reliability the task of allocating subsystem' s, a budget for performance was based on

1. their respective role in delivering a functional requirement and
2. the complexity of the subsystem and any known failure rates.

An example of this is shown in figure 7.

RELIABILITY	90% of services to run on time to within 3 minutes of CityMet timetable (and 5 minutes of Outer Suburban time table) over any 24 hour period (include bussed services measured against train timetable). Maximum of 1% of services to skip any one station in any 24 hour period. Timetabled intertrain connections to be made for 99% of services in any 24 hour period.	Minimum reliability in a 24 hour period of 94.868%. *Bondi Junction to Hurstville Services:* Maximum failure rate of 0.00019956 (i.e. 19 train trips delayed more than 3 minutes out of 96,000 train trips in a year). **Corridor:** *Bondi Junction to Hurstville Services:* Minimum reliability in a 24 hour period of 99.475%. Maximum failure rate of 0.00001994. Applies to failure modes such as in tunnel flooding, cuttings, tunnels, embankments. **Stations:** *Bondi Junction to Hurstville Services:* Minimum reliability in a 24 hour period of 99.737%. Maximum failure rate of 0.00000998. Applies to failure modes such as in station dwell time, lighting. Maximum failure rate of 0.00002993. Applies to failure modes such as in station dwell time, lighting. **Track Structure:** *Bondi Junction to Hurstville Services:* Minimum reliability in a 24 hour period of 98.432%. Maximum failure rate of 0.00005986. Applies to failure modes such as rail breakaway, buckles, temporary speed restrictions.

FIGURE 7

The results of this work was put to value management workshops to verify or refine the functional analysis and the performance requirements.

Overall the process followed for this iteration is summarised in Figures 8 &9.

The workshops were carried out in several stages comprising a strategic diagnosis meeting and a two-stage Value Management workshop .

The strategic diagnosis identified the major issues and areas of concern to be addressed in the value management workshop proper, and confirmed participants and scheduling.

Using traditional Value Management methodologies as set out in the Australian and New Zealand Standard for Value Management, the workshop proper considered each of the following sub-systems in turn to identify the preferred target configuration for the infrastructure;

1. Train Safeworking Method and Infrastructure
2. Track structure
3. Corridor
4. Stations
5. Electromotive power
6. Communications

The basic process adopted in each case was;

- verify the system requirements for the infrastructure,
- to carry out a functional analysis for each of the sub-systems,
- utilise the various proposals in the draft Asset Management Plan provided by City Rail to generate descriptive options for the target configuration and other configurations which may have been applicable.

Using the sub-system requirements as set out in the draft Asset Management Plan as the starting point for determining evaluative criteria in conjunction with the functional analysis, the Value Study group then determined the preferred target configuration in each of the sub-systems.

Following detailing of the advantages/disadvantages of the options, the group selected and weighted evaluative criteria (using a paired comparison technique for the weighting) and evaluated the two viable options using the Value Ratio (performance against evaluative criteria divided by cost) to determine the preferred option.

The Value Ratios of the two viable options were not different enough to give a clear choice, so the group agreed that detailed analysis should be undertaken in the Economic Evaluation.

Illawarra Division Infrastructure Planning Process 1995

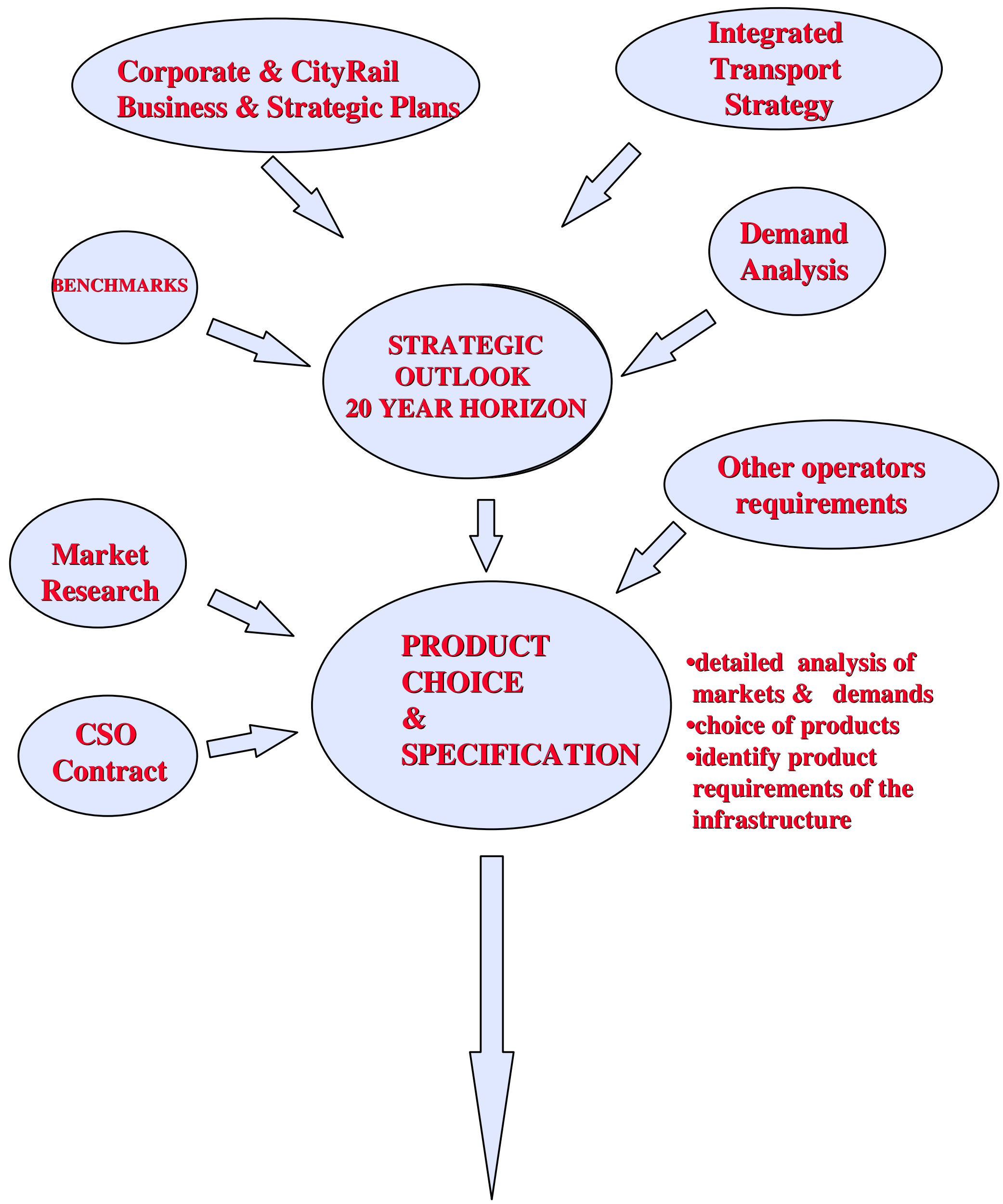


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FIGURE 8

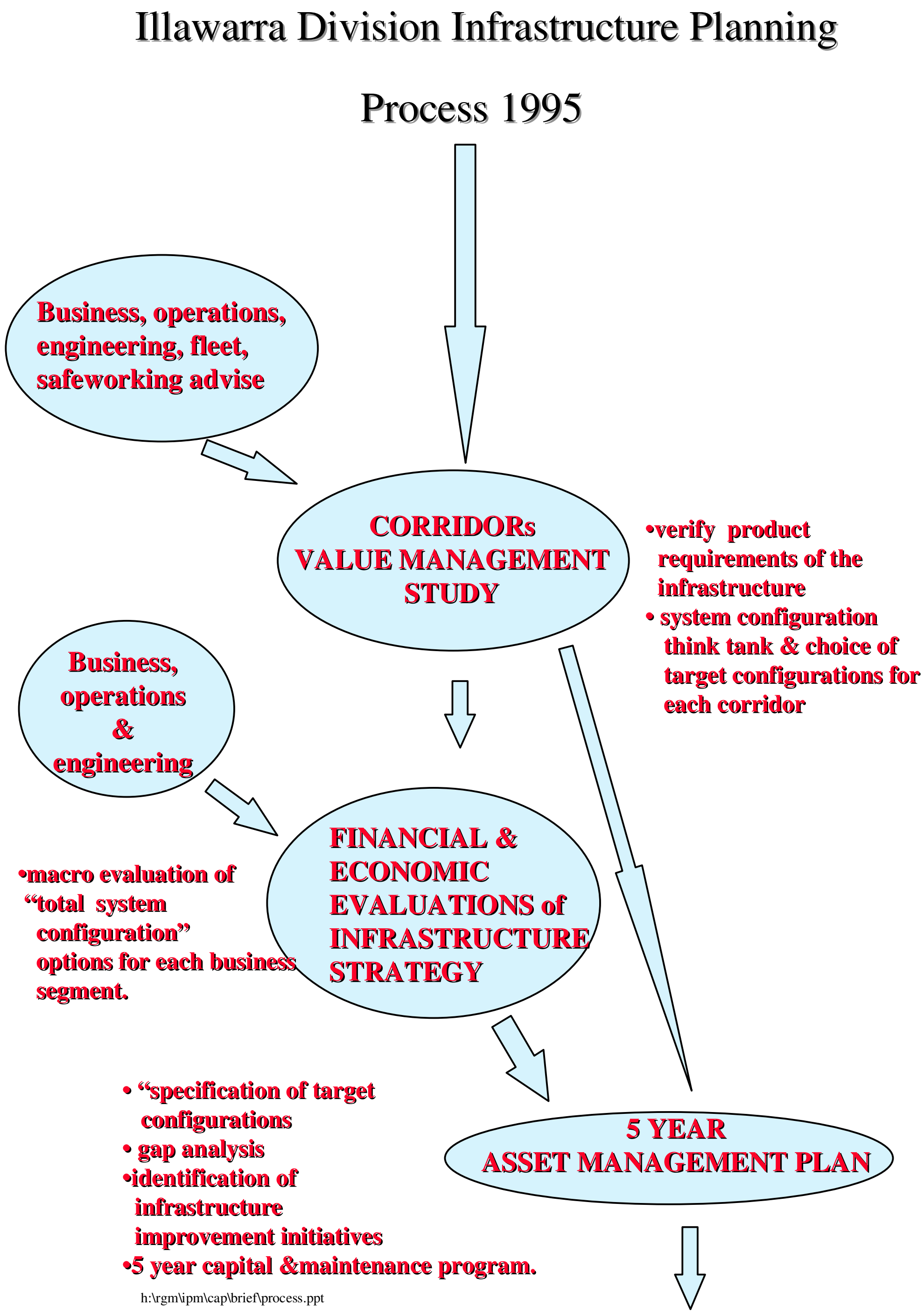
Illawarra Division Infrastructure Planning
Process 1995
Business, operations, engineering, fleet, safeworking advise
CORRIDORs VALUE MANAGEMENT STUDY
•verify product requirements of the infrastructure
• system configuration think tank & choice of target configurations for each corridor
Business, operations & engineering
FINANCIAL & ECONOMIC EVALUATIONS of INFRASTRUCTURE STRATEGY
•macro evaluation of "total system configuration" options for each business segment.
• "specification of target configurations
• gap analysis
•identification of infrastructure improvement initiatives
•5 year capital &maintenance program.
5 YEAR ASSET MANAGEMENT PLAN
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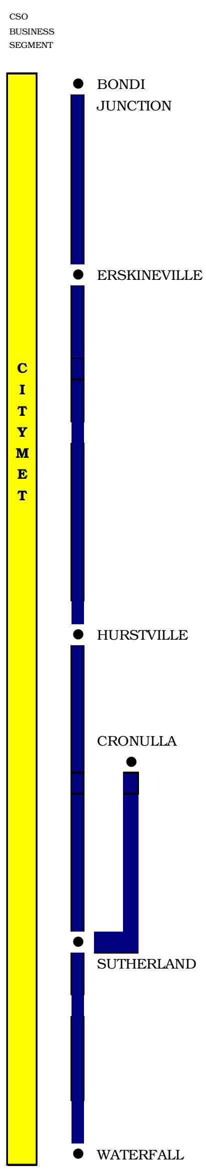
FIGURE 9

Current configurations and existing change programs for the system were examined in assessing the sub-system configurations actually required. A critical issue addressed in analysing the infrastructure configurations was the extent to which change programs improved business revenue, as well as reduce life cycle costs.

The process showed up the weakness in the documented knowledge on performance of different configurations in relation to the performance requirements. Selection of the target configuration in the end came down to the engineering judgment of the sub-system specialists.

Target configurations selected are summarised in Figure 10.

TARGET CONFIGURATIONS
ILLAWARRA SECTOR



BONDI JUNCTION TO ERSKINEVILLE

CIVIL	ELECTRICAL	SIGNAL	STATIONS
* Concrete track bed * 50 kg/m rail * CWR * TCI 28 to 30	* Twin contact * Independently registered * Regulated on viaducts	* Doubleline TrackBlock, automatic * Yard working at Bondi * Centralised control	* All major stations
* Terminating Roads at Bondi Junction, Martin Place, Central			

ERSKINEVILLE TO HURSTVILLE

CIVIL	ELECTRICAL	SIGNAL	STATIONS
* Concrete sleepers * CWR * 60 kg/m rail * TCI 28 to 30 * Fully fenced	* Twin contact * Independently registered regulated * Auxiliary feeders Meeks Rd, H'ville Como to Loftus	* Double line TrackBlock * Centralised Control	* Major stations Sydenham, Wolli Creek, Rockdale, Kogarah and Hurstville
* Terminating road at Hurstville * Stabling at Hurstville			

HURSTVILLE TO CRONULLA VIA SUTHERLAND

CIVIL	ELECTRICAL	SIGNAL	STATIONS
* Concrete sleepers * CWR * 60 kg/m rail * TCI 28 to 30 * Fully fenced	* Twin contact * Independently registered & regulated	* Single & double line TrackBlock, automatic * Bidirectional (H'ville to S'land) * Centralised control	* Major stations Mortdale, Jannali, Sutherland, Miranda, Cronulla Caringbah
* Sutherland loop * Stabling Mortdale, Sutherland, Cronulla			

SUTHERLAND TO WATERFALL

CIVIL	ELECTRICAL	SIGNAL	STATIONS
* Concrete sleepers * CWR * 60 kg/m rail * TCI 28 to 30 * Fully fenced * Existing alignment & grade	* Twin contact * Independently registered & regulated * Auxiliary feeders Loftus to Engadine	* TrackBlock, automatic * Bidirectional * Centralised control	* All stations less than major.
* Stabling at Waterfall			

* All configurations chosen to deliver Product Requirements

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FIGURE 10

The gap between target configurations and existing configurations generated the development of a detailed 20 year horizon program with a detailed year by year program for the first 5 years.

The decision on the program priorities was aided by the macro level of the analysis. Over 2000 projects were listed to achieve and maintain the target configurations across the whole Illawarra Division Corridor. Looking at the business drivers, the performance requirements and the project characteristics, it was possible for each segment system to have projects grouped into less than 50 initiatives. Each initiative project having a synergy in delivering a business outcome.

Initiatives developed, include not only the configuration change projects but also projects which implement changes to maintenance and operating processes. Attention to this had been seen to be deficient in past change programs such as track structure upgrading. Failure to introduce new maintenance regimes to support the higher quality track structure lead to loss in the value of the new configuration. The new track structure quickly lost its original durability and its cost advantage. Maintenance can be categorised as either major periodic or routine.

Major periodic maintenance is required to:

- Maintain infrastructure availability and safety with low routine maintenance costs;
- Avoid accelerated degradation due to dynamic loading on track with poor geometry or excessive maintenance intervention to infrastructure;
- Reduce infrastructure failure risks;
- Avoid devaluation of the infrastructure asset.

Implementation of new maintenance strategies depend on specific initiatives targeted at reducing total capital and maintenance costs. In some cases the target configuration is for a higher condition quality. In these cases major periodic maintenance is targeted to reduce the condition gap between target and actual infrastructure condition as well as maintain the new condition. The gap being progressively bridged over the life of the asset component (e.g. ballast, rails, fastenings, sleepers etc.).

Once initiatives were established a number of program scenarios were developed by accelerating and slowing down various initiatives to suit likely funding levels. The selected program based on judgement about the relative priorities between initiatives

Example of the outcome of this first iteration are summarised in figure 11 for the CityMet System.

	INFRASTRUCTURE INITIATIVES TO DELIVER BUSINESS REQUIREMENTS								
	(INCLUDING MARKET SHARE INITIATIVES)				($000)				
	SECTION INITIATIVE CODE	Recds	1996/97	1997/98	1998/99	1999/00	2000/01	2001/02-2005/06	2006/07-2010/11
1 Bondi - Hurstville									
	1.0 Erskineville-Hurstville track strengthening & intro.0. of new maint. regime	13	5484	0	3349	3185	4666	0	0
	2.0 Mortdale-Carlton Infrastructure Renewal & Rationalisation	6	1390	0	0	0	0	0	0
	6.0 Rockdale Regional Interchange/TOD	4	1504	300	0	0	0	0	0
	7.1 Kogarah Regional Interchange/TOD stage 1	1	4600	0	0	0	0	0	0
	7.3 Kogarah Regional Interchange/TOD stage 3	3	441	0	0	0	2850	0	0
	8.0 Hurstville Regional Interchange /TOD	3	450	0	0	0	0	500	0
	9.1 Minor works and up-grading for class A stations stage 1	2	13	792	0	0	0	0	0
	9.2 Minor works and up-grading for class A stations stage 2	1	100	0	0	0	0	0	0
	9.3 Minor works and up-grading for class A stations stage 3	56	1040	5518	9340	5900	1800	1000	0
	10.3 Minor works and up-grading for class B stations stage 3	9	970	5	400	0	0	1759	0
	11.2 Minor works and up-grading for class C stations stage 2	2	65	0	0	0	0	0	0
	11.3 Minor works and up-grading for class C stations stage 3	8	1480	600	400	994	0	0	0
	12.0 Wolli Creek Regional Interchange/TOD & Xovers	2	800	0	10000	0	0	0	0
	14.0 ESR signalling reliability improvement	3	2075	250	0	0	0	0	0
	16.0 Bridge renewal & intro. of maint. regime	22	924	434	354	354	354	1770	1770
	17.0 Corridor fencing & intro. of new maint regime	1	5	0	0	0	0	0	0
	19.2 Environmental protection stage 2	5	87	30	30	30	0	0	0
	20.0 South Division Only Infrastructure	6	38	0	36	2394	3185	0	0
	49.0 Fire & Accident Safety Aids	1	75	0	0	0	0	0	0
	57.0 ESR track structure rehabilitation	4	115	419	0	0	0	0	0
	61.0 ESR Turnaround Capacity & Operational Robustness	11	0	0	0	0	4542	2250	0
	62.0 ESR Bondi Beach Extension	2	0	0	0	0	0	0	35000
	63.0 Illawarra Locals to Mains Operational Improvement	1	0	0	0	0	0	400	0
	9003.0 Major periodic maintenance track structure	178	3478	1816	1246	1232	2300	13063	13915
	9005.0 Major periodic maintenance fencing	18	98	88	88	88	88	485	485
	9023.0 Major periodic maintenance track structure(South Division Only areas)	71	1689	323	189	109	65	764	1430
	SUBTOTAL	433	26921	10575	25432	14286	19850	21991	52600
2 Hurstville - Cronulla									
	2.0 Mortdale-Carlton Infrastructure Renewal & Rationalisation	1	5056	0	0	0	0	0	0
	3.0 Sutherland area (Mortdale-Cronulla) Inf'struct. renewal & rationalisation	29	9565	21330	4210	100	0	0	0
	5.0 Sutherland to Cronulla track strengthening & intro. of new maint. regime	5	116	0	0	0	1008	0	0
	9.3 Minor works and up-grading for class A stations stage 3	2	50	2	0	0	0	0	0
	10.2 Minor works and up-grading for class B stations stage 2	2	100	250	0	0	0	0	0
	10.3 Minor works and up-grading for class B stations stage 3	8	187	1720	590	0	0	0	0
	11.2 Minor works and up-grading for class C stations stage 2	1	100	0	0	0	0	0	0
	11.3 Minor works and up-grading for class C stations stage 3	3	10	240	0	0	0	0	0
	13.0 Introduction of new track maint regime Hurstville to Sutherland	3	366	0	0	0	0	0	0
	16.0 Bridge renewal & intro. of maint. regime	16	585	35	241	191	91	455	455
	17.0 Corridor fencing & intro. of new maint regime	7	0	0	22	10	0	0	0
	64.0 15 Minute All Day Services Sutherland to Cronulla	5	0	0	2500	0	300	1000	0
	9003.0 Major periodic maintenance track structure	109	2367	2729	1722	1701	1857	10482	9285
	9005.0 Major periodic maintenance fencing	12	66	66	66	66	66	330	330
	SUBTOTAL	203	18568	26372	9351	2068	3322	12267	10070

FIGURE 11

Program scenarios were also developed for alternative target configurations to those nominated at the value management workshops. Some scenarios also included major corridor deviations. A selection of these scenarios were subjected to macro economic analysis to test the value of the totality of the selected target configurations and the implemented program against alternatives. The analysis differs from the economic appraisal of individual projects, since its focus is to identify a preferred investment program option, which involves a wide range of individual projects. The purpose of the macro level analysis was to test the economic sensibility of the alternatives to give confidence in the overall program' s effectiveness. If the preferred program did not stand out ahead of the alternatives, then a number of programs would be progressed until more mature evaluations developed in later iterations of the process.

The CityMet options ranged from low capital investment current level of service to minimum life cost infrastructure investment with business opportunity & operational robustness investment. The Outer Suburban System Options considered range from minimum capital investment low growth scenarios to opportunity realising investment with high growth scenarios such as those with new tunnel alignments. The Regional System options considered range from low capital investment diesel operated services to minimum life cost infrastructure investment, with electric operated services to Kiama and some opportunity investment such as Oak Flats interchange.

To assist the management of the processes of this iteration and to aid analysis, a spreadsheet database and model known as the Infrastructure Planning Management model (IPMA Model) was developed.

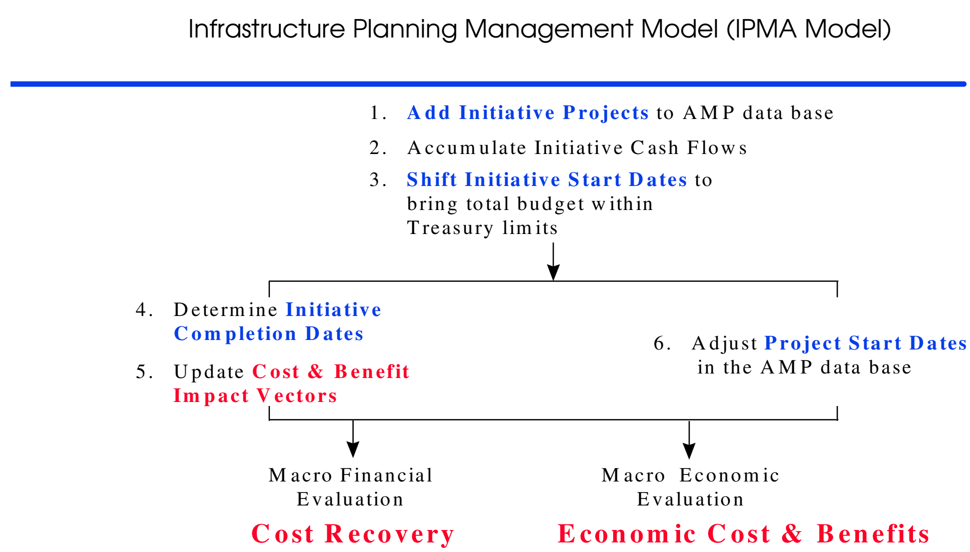

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FIGURE 12

Important to the economic and CityRail financial analysis are the increases or decreases in the maintenance and operating costs and revenue coming from system configuration change initiatives. A system financial model was developed as part of the IPMA Model for the first 5 years reflecting the impacts of configuration change on maintenance and operating costs

5 Year Reports from the Financial model

1. Income & Expenditure Statement (Including Cost Recovery)	Annualised Capital Costs, Non-Capital Cost/Year, Total Costs Per Year, Fare Box Revenue, CSO Support, Freight Contribution, Total Income, Surplus / (Deficit), Cost % Recovery.
2. Balance Sheet	Asset costs, accumulative depreciation & written down value for infrastructure and fleet. Government and non-government funding and total capital employed.
3. Fleet Expenditure Plan	Rolling Stock, Maintenance Facilities, Cleaning Facilities, Stabling, Environmental
4. Infrastructure Procurement & & Maintenance	Stations, Track Structure & Corridor, Electric Motive Power Safeworking, Information Technology, Environmental & Office
5. Operations Expenditure	Station operations, train crew, train control, fuel / energy costs
6. Capital Investment Summary	Stations, Track Structure and Corridor, Electric Motive Power, Train Safeworking, Rolling Stock, Fleet Maintenance Facilities, Fleet Cleaning Facilities, Stabling, Information Technology, Environmental & Office
7. Annualised Procurement Costs	Stations, Track Structure, Electric Motive Power Safeworking, Information Technology, Environmental & Office

FIGURE 13

Revenue impacts were not readily quantified as dates were not available at this point in the planning. The approach taken here was to take a sensitivity approach with a range of % increases in revenue being nominated for each scenario. These assumptions would be monitored and adjusted as the market research and passenger response to projects became known.

3 SYSTEM'S ENGINEERING APPLICATION TO PROGRAM INITIATIVES.

Following the establishment of the change program the next iteration of the System Engineering Process was to apply the process to the development of the individual initiatives.

At the beginning of 1996 the process was largely applied to an Initiative to improve the signaling, electrical and track layout infrastructure for a 17 km section of the CityMet System between Oatley - Sutherland - Cronulla. A value management workshop was convened to start the process. The performance requirements, target system configuration baselines from the first iteration were drawn into this next level of analysis along with the documentation of value management and macro economic evaluation. A difficulty encountered was the tendency for the new participants in the study team to try to start the process anew without any reference to baselines developed earlier. An additional complexity was the change to the business drivers since the first baselines were established. The business managers deciding to alter the product to target a significant increase in patronage from 5% to 20% over 5 years. This required a higher frequency off peak timetable, resulting in the need for additional infrastructure capacity.

Product design was developed starting with the development of timetables with differing off peak frequencies. A consideration in the product design was the feeder bus service nominated in the Local Government's public transport strategy. Infrastructure configurations required to accommodate the altered timetables were identified. These were financially and economically evaluated to select the most viable. Revenue streams were identified for each option.

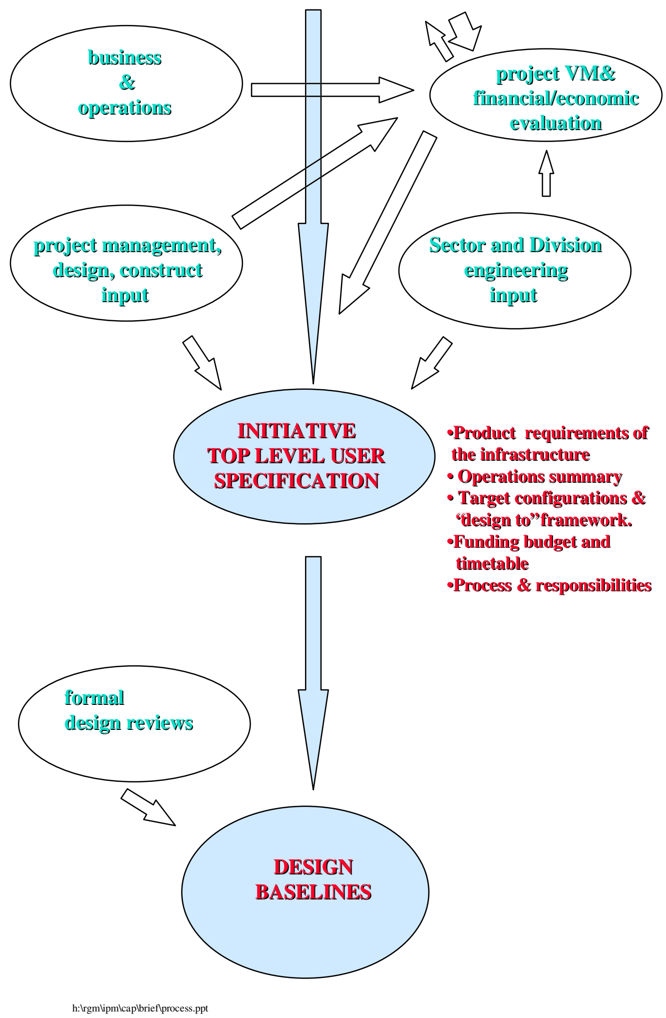

FIGURE 14

While the capacity and life cycle requirements were strongly considered in this iteration, the maturing of the knowledge on how well the system configurations satisfied reliability requirements did not progress greatly with this iteration. Although the risk management study and economic analysis did develop this a little.

The output of this iteration was documented in a new document titled a "Top Level User Specification".

This top level user specification sets out a framework for the design and construction of the Oatley - Sutherland - Cronulla Infrastructure Initiative. Included in the initiative are signal renewal, trackwork and traction supply projects. The document was prepared with the

objective of ensuring the delivery of completed projects consistent with the business, operational and infrastructure requirements for which the initiative had been planned.
The document defines:

- Business requirement of the project;
- Operational requirement and constraints;
- Product requirements and configuration of the completed project;
- Scope of works;
- Project funding and program;
- A design framework requiring traceability to the planned outcomes;
- A project management framework for Management plan, Relationships Co-ordination meetings, Reporting, Project variations, Safety, environment, quality assurance and risk management and Hand over requirements.

This document serves as a base reference for the business client, initiative coordinator, project managers, designers and constructors. It is the basis of a common understanding on how the project is to be carried out.

The contents of the specification is outlined as follows:

10.1 Management plan

10.2 Stakeholders and relationships

10.3 Client and customer interface

10.4 Design and construction management

10.5 Co-ordination meetings

10.6 Program, cost and budget control

10.7 Variations

10.8 Track possessions

10.9 Safety, environment, quality, and risk management

10.10 Configuration management

10.11 Project reviews

10.12 Reporting and documentation

10.13 Handover

The purpose of the document was to convey the business drivers, performance requirements, configuration baseline data and design development processes expected to be followed by the design and review teams in the next level of design development.

At this point the project management traditionally picks up a project for design development and implementation. The Top Level Specification is also aimed at influencing this process to take on a System's Engineering methodology by specifying the following design framework. The aim is to reduce any: "throwing over the wall" tendencies, to facilitate greater understanding of the objectives and how they are to be realised and to establish traceability of design decisions to the functional requirements of this specification

3.1 Design Configuration Management

Design is to be approached as the design of a configuration change from one operating system to another. Intermediate steps or construction stages also require consideration as configuration changes. In this respect the design of infrastructure under the different projects (trackwork, signaling and traction supply) is to be integrated to ensure the functioning of each subsystem and the system as a whole.

3.2 Design Review

The design review is to assess and document the following:

- Satisfaction of the product requirements and target configuration. In particular, the reliability of systems components are to be documented and where possible supported by numerical data. The overall system is to be assessed, in at least a qualitative manner, for reliability risks.
- Functionality of the combined design with respect to the operating requirement of Section 3. In particular the functioning of the design to meet the anticipated operating improvements outlined in Section 3.3 is to be assessed;
- Constructability of the design, particularly in relation to a proposed possession program;
- Estimated costs in relation to assumptions in the Investment Evaluation (i.e. estimates updated);

- Satisfaction of the benefits assumed in the Investment Evaluation;
- Identification of design and construction risks with appropriate risk reduction or mitigating procedures;
- Flexibility for future operational changes such as introduction of 15 minute off-peak services;

4 FURTHER APPLICATION OF THE METHODOLOGY

Applying the System's Engineering methodology to macro system planning, has shown its value in the CityRail Illawarra pilot. The result was significant improvements to both business and infrastructure planning. Earlier analysis of systems in the formative planning stages, reducing the cost coming from needing changes when designs are more mature and complex to change. Greater assurance that selected infrastructure will provide its intended role in delivering the product.

The processes piloted are able to be refined and applied to new product design , to assist in evaluating the proposed products value to the business and the community. For example it recommended that the " House of Quality" technique is a useful tool in providing traceability in the development of design requirements from the product attributes identified. A particular application is in quantifying the attributes sought by customers, raised at focus groups in the target market segments.

Application of the System's Engineeri ng process in the later design stages would best be managed through the formulation of Systems Engineering management plans tailored to the level of complexity needed for the Subsystems being designed.

Asset condition data baselines was particularly deficient in the CityRail pilot. Development of these for the assets making up each Subsystem would strengthen the quality of the decision making when it comes to matching configuration performance to performance requirements.

The financial model component of the IPMA model provides a simple appreciation of the impacts of product changes and initiative timing to the overall business performance. Refinement of the maintenance cost, operating cost and revenue impact vectors in the system financial model will strengthen the inputs to the business decision between product options. Using this capability to provide quick "what if" input at product and program review meetings is a useful further application. It may be possible to extend this to an economic model to similarly look at community impacts of different product options in the future .

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