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Driving the performance of your business

Workbook

Contemporary Scheduling



PITCHER PARTNERS
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PRODUCTIVITY
LEADERSHIP



Phillip Boyle
& Associates



PITCHER PARTNERS
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1. Introduction

This booklet is third in a series, which builds on the “driving business performance” presentations delivered at the 2014 Bus Industry Confederation Conference. This workbook looks at the art and science of contemporary scheduling, and refers back to the booklets on *Business Strategy* and *Performance Measurement*.

The first workbook provided a guide to developing a strategy for your overall business. This process allowed for the reflection of your business objectives, and what it is you are trying to achieve as an operator (as opposed to what you do). The second workbook of this series provided a step by step guide to performance measurement. This helped to build on your strategy to identify the most relevant measures for the success of your strategy and managing the performance of your business. Timetabling is one of the key drivers of the efficiency of your business, and defines most outcomes downstream.

From a high level, your strategy tells you where you are going as an organisation. Your performance measurement tells you if you are delivering on your strategy by collecting data, reporting, and identifying when you need to take action to keep on course for your strategy. Scheduling is one of the key tools for an operator to deliver on strategic objectives, the success of which is assessed by your performance measurement.

As an operator navigating the scheduling process, you should be seeking to understand how your operations fit in to the larger network in which you operate. Contemporary scheduling allows you to move from timetabling based on “what’s always been done” or “what feels right” to delivering a service that meets the objectives of your organisation, regulators and passengers. Importantly, you will be able to produce measurable results and comparisons for your scheduling solutions.

It can be seen that scheduling is not a compartmentalised process. No one part is separate from other parts. Scheduling should not be considered as separate from your strategy, or the performance of your business.

This workbook will help you through the process of understanding what scheduling is (and isn’t), what factors need to be considered, how to test your assumptions, and avoid many of the common pitfalls of scheduling that operators face in their businesses.

Before moving through this process we will review key concepts from other workbooks in this series, as well as introduce terminology which will be used throughout this book.

2. Terminology¹

Block is a vehicle assignment that includes the series of trips operated by each vehicle from the time it pulls out to the time it pulls in. A complete block includes a pull-out trip from the garage followed by one or (usually) more revenue trips and concluding with a pull-in trip back to the garage.

Blocking is the process in which trips are “hooked” or linked together to form a vehicle assignment or block.

Clockface Headway is the scheduling of headways on even and repeating intervals. This is also known as “Memory Headway”

Customer is the term we have used for your passengers or PAX in guides one and two, and will be used throughout this workbook.

Cycle time equals the round trip running time plus layover time. This is also known as “roundtrip cycle time” or “roundtrip time.”

Deadhead is the time and distance that a bus needs to travel between service locations during which it will not pick up passengers. Deadheading is typically required to get buses to and from their garage, or to travel from one route or point to another during their scheduled work day. Also known as “non-revenue travel.”

Deadhead hours include pull-in time, pull-out time, and deadhead time from one route or point to another.

Deadhead kilometres include pull-in kilometrage, pull-out kilometrage, and deadhead kilometrage from one route or point to another.

Frequency is the number of vehicles passing a point on a route within a given unit of time, usually expressed as X vehicles per hour. See also “headway.” Headway is the inverse of frequency: a frequency of 6 buses per hour is equivalent of a headway of 1/6 of an hour or 10 minutes.

Headway is the interval of time between two vehicles running in the same direction on the same route, usually expressed in minutes. See also “frequency.” Frequency is the inverse of headway: a headway of 10 minutes is equivalent to a frequency of one bus every ten minutes or six buses per hour. “Headway” is sometimes used by operations personnel to designate a gap in service or a missing bus.

Crew scheduling is the process of converting (or cutting) vehicle blocks into work assignments for operators. The finished product is sometimes referred to as a roster. However a roster is more accurately defined as the work packages during a set period (e.g. a week or a month).

Shift is a work assignment for an operator. Most often, run refers to a whole day’s work assignment. This is also known as a “Driver Shift” or a “run”.

Timetable is a document containing route and time information produced for use by PAX.

¹ The terminology used here, while common in use have been drawn (and adapted for an Australian context) from the February 2009 scheduling manual “TCRP Project A-29; Controlling System Costs: Basic and Advanced Scheduling Manuals and Contemporary Issues in Transit Scheduling” authored by: Benn, H; Boyle, D; Boyle, P; Nelson, B; Pappas, J; Sharfarz, D.

3. Key Concepts

Described below are fundamental principles and concepts of performance measurement. They will assist you in thinking about the types of measures available and where you should be focusing performance measurement within your business.

These principles and concepts are also important to understand in order to complete the four-step process that is discussed later in this workbook. This understanding will also greatly assist you to identify performance measures within your business.

The fundamental principles and concepts are:

1. Goal Achievement Plan

In developing your strategic business plan as outlined in workbook one, a goal achievement plan (GAP) should have been developed. The GAP details those tasks that should be completed to deliver on the various strategic objectives established in your strategic plan. A key performance measure must be the delivery of these tasks in accordance with the GAP.

2. Key Indicators²

Key indicators can be categorised into two broad categories those that tend to look to the past and those that seek to look towards the future:

2.1 Key Results Indicators

Key Results Indicators (backward-looking measures, also called lag indicators) are measures that focus on past performance. They tell you how well you have performed against expectations. Whilst they reflect performance against expectations they don't necessarily highlight what action is required to shift poor performance up to expectations or what has delivered a performance above expectations.

For a bus operator some examples of backward-looking measures are:

- *Cost per kilometre last month*
- *Bus hour cost last month*
- *Net profit to date*
- *Overtime hours last month*

2.2. Key Performance Indicators

Key Performance Indicators (forward-looking measures, also called lead indicators) are measures that provide an indication as to whether you are on track to achieve expectations. Forward looking measures usually focus on key indicators of performance that are most critical for current and future success. They are almost always non-financial measures that reflect trends that will either lead to performance above or below expectation. They should be simple to understand but again may not clearly indicate what is giving rise to the measure. They are highlighting how that trend may impact future results.

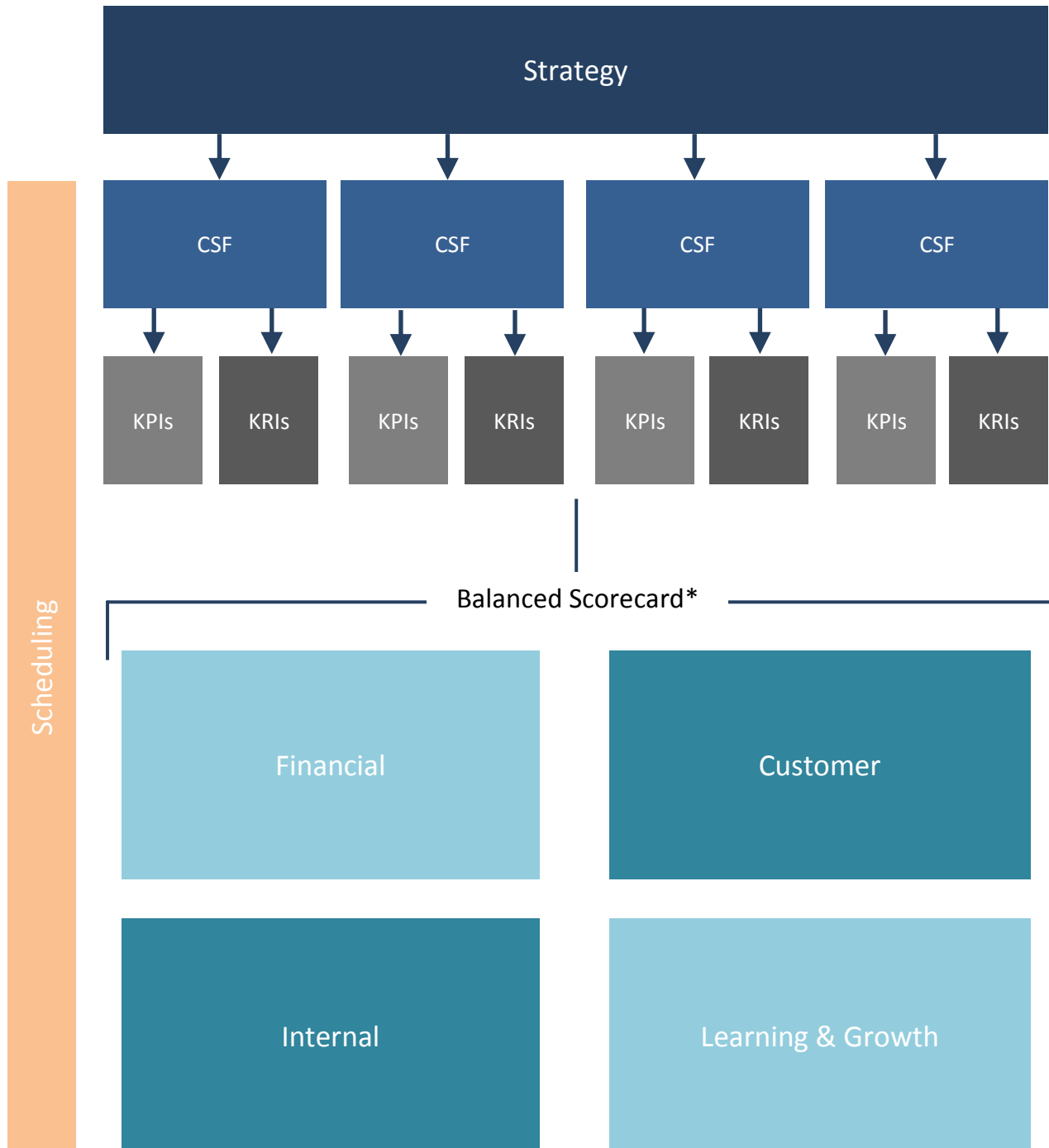
² The terminology and definition for Key Results Indicators, Key Performance Indicators and critical success factors noted below, while common in use have been drawn from the work of David Parmenter "Key Performance Indicators", second edition.

For a bus operator some examples of forward-looking measures are:

- *Repairs and maintenance programme on track – if the measure reflects that the programme is well behind schedule it is a likely indicator of future equipment failure leading to reduced timetable performance and possibly higher capital cost in early replacement of plant and equipment*
- *Workplace health and safety record – an increasing incident of accidents above expectations may flag an increased risk of a major incident/accident and all the implications of that on the business*
- *Forward charter bookings – lower than expected bookings may flag a decline in future revenue*
- *Customer survey feedback – a trend of declining survey results may flag a level of increasing customer complaints and the breach of contractual performance benchmarks.*

3. Bringing it all together.

The diagram below brings together the three workbooks in this series and demonstrates the linkage between business strategy, critical success factors, performance measures, the balanced scorecard and how scheduling complements these.



** Each KPI and KRI impacts one or more areas of the balance scorecard.*

4. Starting Your Process

What are the key resources you need to undertake this process?

- Data
 - o Operating information (Deadhead hours/miles, route deadhead distances, running times, service levels, route maps, frequencies, headways, labour agreements)
 - o Fleet information (number of vehicles by vehicle type)
 - o Other operators (intermodal & intramodal)
- Stakeholder viewpoints
 - o Drivers (factors effecting cycle time/block time)
 - o Passengers (connection times plus walk time between intermodal services Can local amenities be accessed at times available –consider late night shopping, market days)
 - o Regulators (defines service levels and quality requirements)

In [section 10](#) we discuss the tools that you can use for contemporary scheduling. There are a number of products that can be used, however many of the graphs and data you will see throughout this workbook have been developed using standard spreadsheet software. Spreadsheets can be incredibly powerful and may provide the flexibility you require in scheduling, measurement and reporting. Throughout this workbook there are exercises where you can outline answers and begin to plot and consider the various elements of scheduling. Excel can be used to substitute many of the response areas provided in this workbook, and serve as a template for your schedule planning.

Who should be involved in the scheduling process?

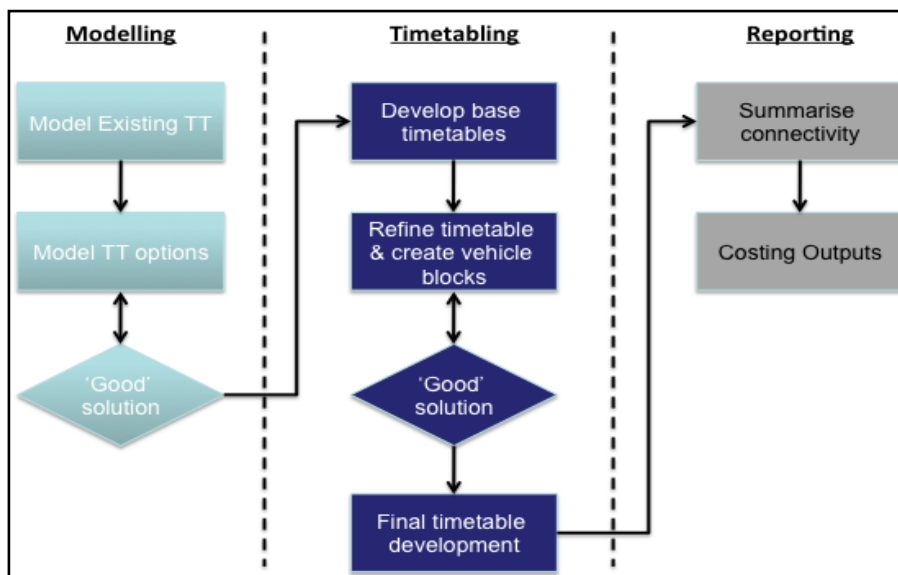
- Business owners/operators
- Drivers
- Key staff to facilitate the process
- Regulators
- Other operators (operators need to understand that they do not operate in isolation, but rather part of a network)
- Labour unions (in some cases)

In [section 9](#) we review the second workbook in this series to help set performance measures. Planning and implementing performance measures within an organisation requires engaging people with core knowledge of the organisation. When designing performance measures, different people within the organisation will have different understandings of success factors of the organisation. This workbook on scheduling can assist in guiding these understandings.

5. The Key Components & Challenges of Contemporary Scheduling

Three Stages of Contemporary Scheduling *

1. Modelling
 - a. Model Existing Timetables
 - b. Model Timetable Options
 - c. Decide parameters for what is a 'good' solution
2. Timetabling
 - a. Develop Base Timetables
 - b. Refine Timetable and Create Vehicle Blocks
 - c. Acceptance of preferred solution
 - d. Final Timetable Development
3. Reporting
 - a. Summarise Connectivity
 - b. Costing Outputs
 - c. Service plans



**this model does not include crew scheduling (driver shifts)*

In [Section 11](#) of this workbook, we outline a step by step process of how to undertake the scheduling process. This process is modelled above.

It can be seen that there are a number of decision points which require revision and redrafting (deciding what is a 'good' solution) of solutions. Setting timetables and schedules is an iterative process. It requires comparing solutions against an operators stated objectives, and the key components of scheduling, to determine the 'best' option.

This workbook guides you through the considerations in setting scheduling, however ultimately, the process above is the practical guide to completing scheduling.

Challenges

Developing a 'good' schedule can be a complex process. There are a number of seemingly unrelated aspects which must be addressed.

1. Service Levels

The service level to operate is sometimes unclear. For example, when a contract requires uneven headways (e.g. between 20 and 25 minutes) it is difficult to determine at specifically what times trips should operate.

2. Rules & Constraints

There are two groups of rules in scheduling. The first are those that as an employer or operator you are bound to comply with. These 'hard' rules can be labour conditions or agreements, or operational requirements under contract with regulators. The second set of rules are those that an operator may put in place for any given reason, but which are not necessarily binding. These 'soft' rules could be operating preferences, or any other limitations.

It is important to understand the differences between these, as having a degree of flexibility around operations is essential in finding a balance between the various key components of scheduling. A common scheduling mistake is to apply preferences or 'soft' rules as 'hard' constraints.

3. Tension Between Efficiency & Reliability

- Need to lower costs of operation
- Contestability
- Industrial impacts (in response to tighter scheduling)

Reliability is an aspect which matters to all your stakeholders (drivers, customers, regulators and ultimately operators). However efficiency is of key concern to operators and regulators. Lowering costs can help drive better returns, and result in being more competitive in a contestable process. However in doing this, employees and unions are keenly interested in how this achieved. It takes a degree of skill, consideration and sometimes innovation to meet the demands of both efficiency and reliability in a way that satisfies all stakeholders.

4. Quality

Developing high quality timetables and operating plans is the result of understanding what all stakeholders are looking for. In [section 6](#) we explore how your customers and drivers would define a quality timetable.

While each aspect requires due consideration, no one part of scheduling should be seen as being 'distinct'. The scheduling solution lies in understanding that the process involves addressing all the key components, and evaluating them for the effect they have on each other.

The Key Components

Scheduling comprises many interrelated factors. In particular these are:

- Quality
- Reliability
- Efficiency
- Network Coordination (intermodal and intramodal)
- Performance Measurement and Reporting



Often when we work on achieving one factor, we can compromise on achieving the others. It seems like there is always a tension between scheduling for all these factors, and that striking a balance between them is not always possible.

The challenge for operators is not to see these components as being mutually exclusive, but rather as forces which need to be balanced between one another, based on your business priorities.

In [section 7](#) we discuss the balance between reliability and efficiency. This workbook focuses on improving efficiency as it can be overlooked by operators in the scheduling process, and result in increased operating costs. An example could be an operator adding in deadhead time at the end or start of a route which is not meeting on-time performance. An alternative could be restructuring operations to increase reliability of frequencies or in-service running times, and at the same time could also lower costs. When done properly using the methods and understanding the considerations in this workbook, an operator can achieve both efficiency and reliability.

The first step in finding this balance is knowing where the priorities for your business lie. In the first workbook in this series *Business Strategy* you outlined the priorities for your organisation by completing a Goal Achievement Plan (GAP). Similarly, it is important to understand what your objectives are in setting your scheduling. Scheduling is an important part of an operator achieving its business goals, or its objectives. While having more of an operational focus, these objectives should reflect the goals of your organisation.

These objectives need to be clear and measurable (we will set measurements for this later in the workbook). Your objectives will guide you through the process of scheduling, and act as a validation for success. This allows you to demonstrate to your customers and regulators that your schedules are achieving what they set out to do.

Use the table over the page to plot your objectives. Prioritise them, and remember to keep these clear and measurable.

5.1 Objectives

* *Examples*

Objective	Priority
* <i>"Reduce wait time for passengers, while not increasing costs or associated resources"</i>	1
* <i>"Ensure there are enough services to safely carry passenger numbers"</i>	2
* <i>"Allow sufficient breaks for drivers"</i>	3

6. Timetabling for Quality

Before we discuss what is meant by scheduling quality, let's explore what your thoughts are on quality.

6.1 Write down some dot points on what you think of when you think about quality. Consider different perspectives. What would your customers see as quality? What about your drivers and other staff?

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Operators are under increasing pressure from regulators and from customers to produce quality outcomes.

"Higher standards are being set for service quality, operating quality, efficiency and information"

Scheduling for quality involves five key aspects. They should:

- Satisfy drivers needs and preferences
- Be operationally reliable
- Have high levels of coordination (where applicable)
- Be easy to understand, and above all
- Be simple

What is quality for your customers?

Implications for customers should always be a number one priority.

Consider your passengers. They may catch several modes of transport throughout a day, at varying times in varying locations. When a particular service departs at differing frequencies, this can be difficult for customers to remember. The use of clockface headways can help to resolve this.

Consider the following timetable:

A	B	C	B	A	B	C	A	B
7:52	7:55	8:11	8:34	8:35	8:53	9:11	9:16	9:32
8:03	8:05	8:21	8:44	8:46	9:03	9:21	9:26	9:42
8:13	8:17	8:32	8:56	8:56	9:14	9:32	9:37	9:53
8:20	8:24	8:39	9:03	9:03	9:21	9:39	9:44	10:00
		8:45			9:27			10:06
		8:50			9:32			10:11
8:31				9:14			9:53	
	8:35	8:59	9:15		9:41	9:50		10:20
8:37				9:20			9:59	
8:43				9:26			10:05	
9:02	9:00	9:24	9:40	9:45	10:05	10:15	10:24	10:45

Table 1: Timetable Case Study

6.2 What would be some of the challenges a customer would face with a schedule like the one in Table 1? How can they be resolved³?

Problems	Resolutions

One approach commonly taken by operators in scheduling their blocks is to have their buses continually operating in service as often as possible regardless of their frequency or headway. At first this makes intuitive sense; the quicker buses get through a block and are able to run through again, the more the

³ See [Appendix 1](#) for suggested solutions

operator will be able to service customers. However in reality, a schedule like this can cause confusion by buses arriving at uneven intervals which are confusing to passengers. Consider the following example of using clockface headways.

An operator has the option of setting bus runs every 55 minutes for 5 hours, or every 60 minutes for 5 hours. It may not make immediate sense to have buses idle for 5 minutes at the end of each run, but there are tangible customer benefits⁴ of having the longer 60-minute headway. In particular you would see increased ease of coordination with other services, and have a timetable which is easier for passengers to remember.

As outlined in [Section 5](#), scheduling is a process of balancing several factors.

6.3 In reviewing the schedule in [Table 1](#), assume the operator who created it had very specific reasons for why it was like this. List reasons why an operator may have felt compelled to set their timetables like this⁵.

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Customers (and regulators) want to ensure that all local amenities can be accessed. This includes late night shopping, market days and library hours for example. Consider how likely your customers are to make connectivity with other modes of public transport (both buses and trains), and how long it will take them to walk between stops. In [section 8 Networks and Coordination](#), we will explore scheduling for networks further.

What is quality for drivers?

Herzberg's Two Factor Theory⁶ is a psychological theory that is applied to satisfaction in the workplace. It states that there are motivators in the workplace which give positive satisfaction, and then there are hygiene factors which are the bare essentials an employee expects, but do not add to their positive ratings of their job; however, if hygiene factors are not met, then they will be dissatisfied with their work. Among these hygiene factors are work conditions and organisational policies.

Take a look back at [Table 1](#).

⁴ Currie, Graham (2011). *Analysis of the Long Headway Service Coordination Issue*. Booz, Allen, Hamilton.

⁵ See [Appendix 1](#) for suggested solutions

⁶ Herzberg, Frederick; Mausner, Bernard; Snyderman, Barbara B. (1959). *The Motivation to Work* (2nd ed.). New York: John Wiley.

6.4 What are some of the issues that might cause dissatisfaction for drivers in this schedule? How can they be resolved⁷?

Example: "Not having enough recovery time built into blocks, and being under pressure to make up time in other ways" or "Drivers find it difficult to remember headways or running times that change throughout their shift."

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Your drivers are the public face of your business, and ultimately are those that deliver the schedules that are created. Considering the elements that might affect drivers before setting a schedule helps to avoid having to make changes 'on the fly' in response to staff that are unhappy or identify issues.

How familiar are you with each of your routes? When did you last ride them as a passenger? An easy way to understand some of the practical impacts on a route is to go on runs with your drivers. This is a simple way to understand your drivers' concerns first hand, and consider practical solutions that agree with your other objectives.

Timetables and operational quality

"The best scheduling solutions provide an operating plan designed for easy execution"

The way in which your operations are structured will have a flow on effect for your drivers, blocks, customers, and ultimately you will have to find solutions to adverse issues that arise.

6.5 Detail below your understanding of some of the current issues that affect your scheduling solutions.

Example: "Congestion in particular areas causing flow on effects for subsequent blocks."

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⁷ See [Appendix 1](#) for suggested solutions

Consider the figure below:

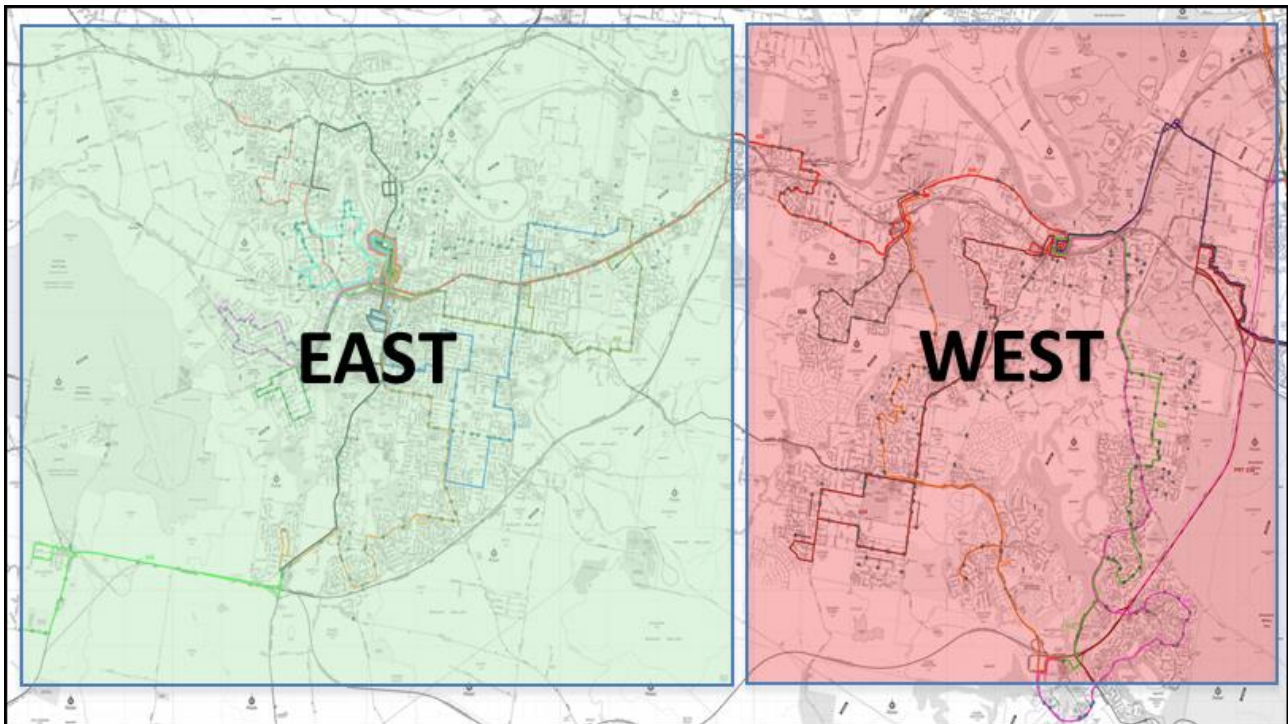


Figure 1. Sample operational layout

How does this compare with your operational layout? A simple separation of operations which has work rosters split into east and west like the one in figure 1, that has been tested, either through personal experience or that of your drivers, can result in reduced driver training, and less ‘flow on’ effects throughout the system. An operation like this can also result in less deadheading by reducing the need to cover greater distances. Such a solution should of course be tested against an ‘all-in’ approach for efficiency differences. When you understand both the costing and quality impacts, you can make an informed decision.

Operational quality reflects how well you have considered your customers and your drivers in setting a schedule. An operating plan that is of a good quality will be one that all stakeholders are happy with:

- Drivers
- Customers
- Regulators
- Owners / Operators

‘Hard’ Versus ‘Soft’ Rules

A final consideration in quality is to clearly understand the difference between the rules which are absolute within your scheduling process (such as those relating to labour agreements, or existing specific ongoing operational arrangements) and those that can be adjusted.

Most requirements will not be black and white, and should not be treated as such. This can place an unnecessary constraint and reduce efficiency or service quality.

Imagine as an operator you set a minimum meal time as 35 minutes, even though labour agreements stipulate a minimum of 30 minutes (i.e. 35 minutes is not actually required by any agreement). You have always allowed 35 minutes to ensure a buffer against unexpected late running and changing this is against

the rules you have set for yourself. Now consider it comes to your attention you could save \$50,000 per annum by scheduling a minimum of 34 minutes for a few instances during off-peak or evening periods, when conditions are more predictable. Would you now vary this in your schedule?

This is an extreme example to highlight the point, that having a distinction between what rules are set in stone, and what rules can be adjusted are important.

Bringing it Together

In summary, operational plans and schedules of a high quality:

- Meet operational objectives ([Exercise 5.1](#))
- Are simple and repetitive patterns of operation ([Exercise 6.2](#))
- Minimise complexity (Exercises [6.2](#) & [6.5](#))
- Are preferred for drivers and operations staff ([Exercise 6.4](#))
- Have 'sufficient' run times and recovery times ([Exercise 6.4](#))
- 'soft' rules, not 'hard' rules (Sections [5](#) & [6](#))

6.6 Review your answers to [6.2](#), [6.4](#) and [6.5](#). When considering issues identified, were there similarities between solutions?⁸ If not, consider ways you could change operations or schedules to address these problems. Consider how these fit to your objectives in [5.1](#).

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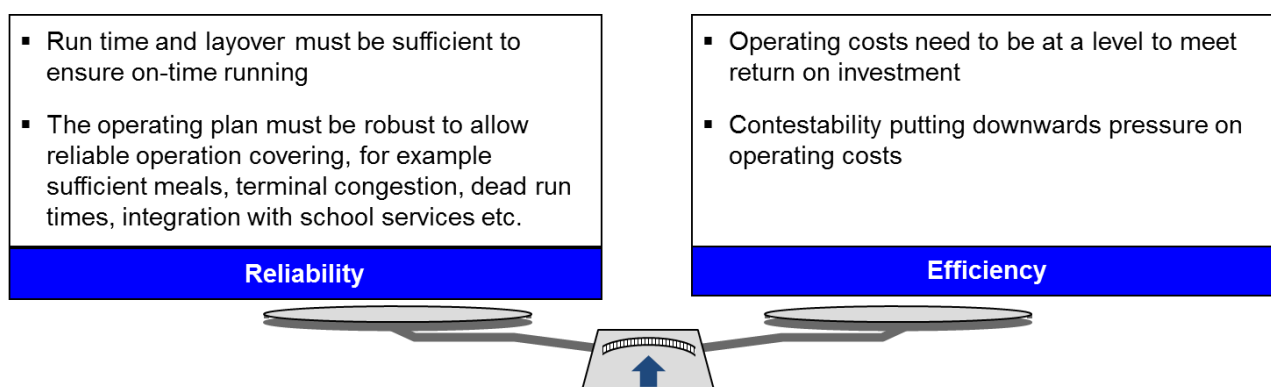
⁸ See [Appendix 1](#) for suggested solutions

7. Timetabling for Reliability & Efficiency

Reliability

“increasing pressure on operators to meet punctuality targets while external forces impact on reliability”

Two of the most difficult factors to balance in the scheduling process are reliability and efficiency. The tension between these make it difficult for operators to strike a balance; focusing on reliability or efficiency alone can mean trading one for the other.



There is increasing pressure from regulators for operators to perform at higher levels of reliability, through penalty and/or bonus schemes. Drivers can add to the pressure to focus on reliability. There are many factors which impact on the desire to schedule for reliability. Allowing extra time in schedules can often resolve these issues, however this is an unbalanced approach. How is it best to address these?

Stakeholders Needs	
Owners Want: <i>Good returns</i> <i>Reliable operations</i>	Customers Want: <i>Faster trips</i> <i>More reliable services</i>
Drivers Want: <i>Reasonable employment conditions</i>	Regulators Want: <i>More reliable service</i> <i>Reduced costs</i>

“Operating speed is the primary driver of operational efficiency”

Consider the ways in which you currently set your running times.

7.1 Outline what information, or the sources of data you use, and processes you follow in setting your running times.

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Under *Quality for Drivers* in [section 6](#) we asked how familiar you are with your runs, and if as an operator you have ever experienced these runs. This is one source of data that is first hand. Many operators have access to large data sets for running times analysis, however these should be supplemented by first-hand observation in all cases.

7.2 Consider the following scenario.

An operator in a regional area has been operating on contracts in their region for over 20 years. This operator is heavily tied up in the administration of running the business, and no longer conducts runs himself. Despite this, and recent development and growth in the region, the operator feels pretty confident with their knowledge of the area.

The current running times have been the same for roughly 10 years, and are closely based on times for previous contracts. When first setting running times for routes, the operator has made sure that there is sufficient time to cover both runs and layover time at the multiple interchanges along routes. Periodically drivers will report congestion on routes leading to schedules consistently running behind. To deal with this the operator surveys a few of the more experienced drivers in the business and takes an average of their estimates of extra time required and adjusts the schedules accordingly. In general, except for these adjustments, the operator finds they are meeting on-time performance.

The operator is now looking to future contracts. The operator, like most other operators today, is facing pressure to reduce costs from contestable processes, as well as seeking to lower costs to achieve a better return on their investment in the business. They are not sure where to start in finding efficiencies for the business, but suspect that there is room to optimise run times which will help increase margins.

Outline some points below about how the operator might start to look at runs to gain efficiencies, or suggest some areas which might help the operator optimise running times based on the information provided in the scenario. How does this scenario compare to the way you plan and schedule your running times⁹?

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Myths & Facts of Running Times Optimisation

- Running time problems are a scheduling issue
Is this due to traffic variability or some other external factor?
- Low on-time performance means insufficient running times
Are buses may leaving the terminus late due to congestion or excess run times?
- Schedule deviation data is a good tool to determine run time requirements
Run time requirements are the result of a number of factors and you should try to generate elapsed end-to-end times for analysis.
- Layover requirements are a function of trip length
Actual time taken by a 30 min route in a CBD may regularly vary by 8 mins, but a 90 min trip in the country may only vary by 2 mins.
- Setting run times is a statistical process
This requires an operational understanding and flexibility.

⁹ See [Appendix 1](#) for suggested solutions

Interchanges and Congestion

"Failing to plan is planning to fail"

The operator in [scenario 7.2](#) has had drivers saying that congestion is causing running times to push out. To deal with this the operator has applied a simple approach of adding extra times to runs, or additional layovers at the end of trips.

This approach may be effective in keeping *reliable* running times, but is it efficient? The operator in this scenario has not considered alternatives, such as what could be causing congestion. In many cases the operational plan itself could be contributing to the congestion, especially in interchanges.

By effective scheduling for bus and bay utilisation, you can reduce congestion and minimise infrastructure costs. Review the two figures below.

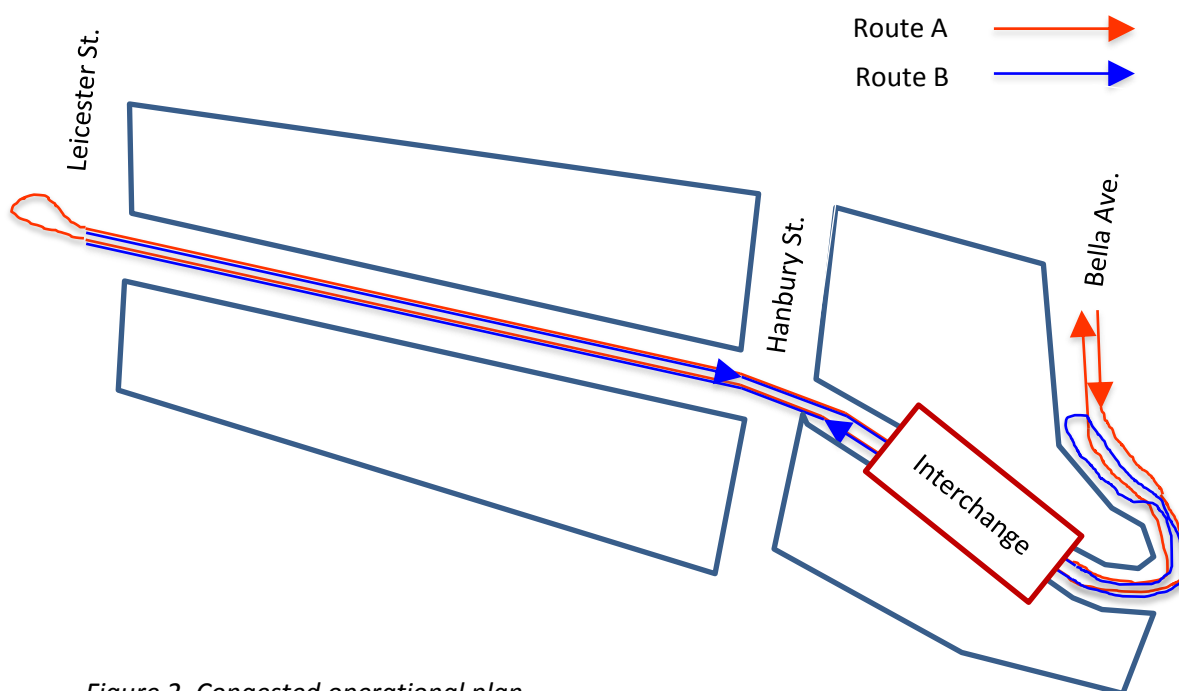


Figure 2. Congested operational plan.

In figure 2 Route A comes in to an interchange from Bella Avenue. To get back out for the next run the bus heads out over Hanbury Street, and u-turns at Leicester Street. Route B does the opposite journey by coming from Leicester street to the interchange, then heads back out along Bella Avenue. The two routes overlap one another, move in the same direction, and double up over one another. This can cause congestion and delays.

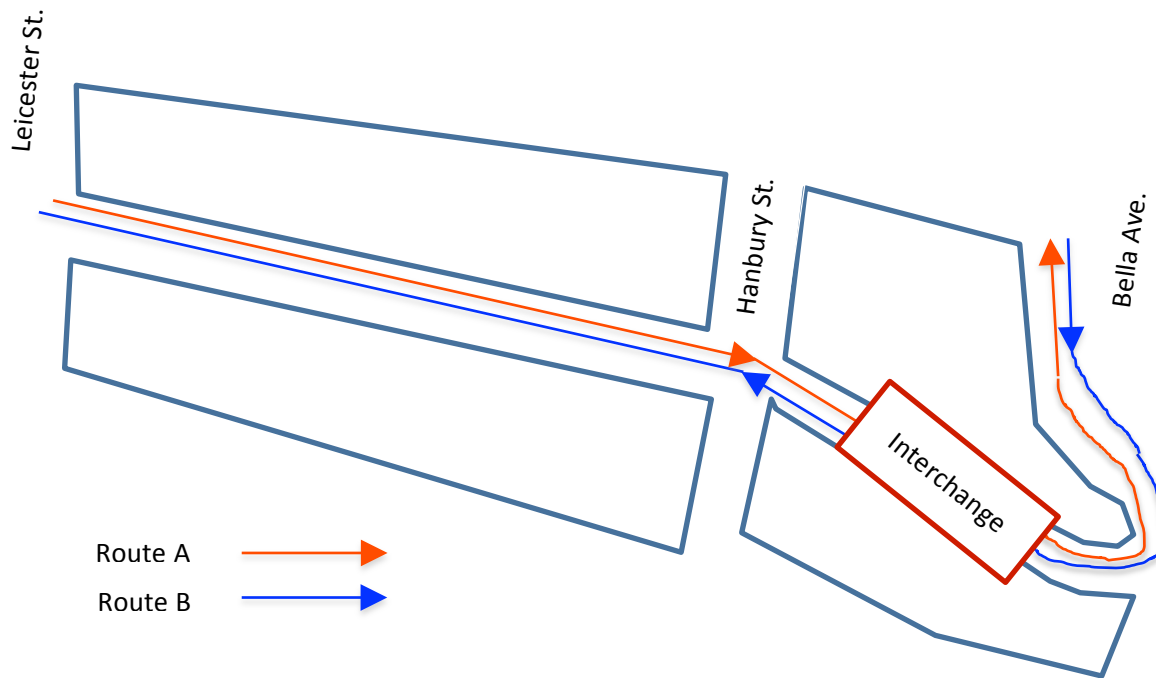


Figure 3. Alternative operational plan.

Figure 3 shows alternative operational plans for both routes. Route A comes in from Leicester Street into the interchange. The next route commences out along Bella Avenue. Route B performs the opposite operation, coming in through Bella Avenue to the interchange, and begins the next run by heading out over Hanbury Street.

This plan eliminates congestion by not having routes A & B running behind each other, and then cross over each other by performing unnecessary u-turns.

Besides the benefit of effectively reducing deadhead hours and kilometres, this is a more elegant solution to increasing both efficiency and reliability, while reducing frustration for drivers and passengers.

8. Networks and Coordination

In [section 6](#) we looked at a schedule in [Table 1](#) which, amongst other points, highlighted the various modes of transport a customer may need to take when completing their various journeys within a day. In a report¹⁰ from the Victorian Auditor-General, it is highlighted that “effective coordination between public transport modes is essential to enable the efficient movement of persons, including access to jobs and services.”

Connectivity between and across networks is another area of scheduling that can seem to be at odds with scheduling for efficiency, as can scheduling for those transferring and not transferring. However this is not the case.

Take a moment and consider the research below from the Monash Institute of Transport Studies¹¹ to understand the importance of coordination from a passenger perspective:

- 25% of bus passenger trips in Melbourne involve a train transfer
- Passengers perceive a penalty of up to 12 minutes for a bus/train transfer at ‘average’ frequencies’
- Passengers value walking and wait time during a transfer at double the actual time
- Clockface or memory timetabling can deliver an additional four-minute perceptual benefit
- ***The bus patronage impact of improved coordination of between 7% and 17% increase for transfer trips, or 3.5% to 8.5% increase to overall bus patronage***

The points above highlight the psychology of your customers in assessing the connectivity of your timetables as part of their overall journey. Connectivity performance is further impacted by the *perceptions* of customers who mentally add to, or subtract from, connection times.

8.1 Consider the network in the region / area in which you operate. How many different types of public transport are there? How many other bus operators do your routes connect with? List below the different modes of transport below your routes interact with, and some of the other bus operators below.

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¹⁰ <http://www.audit.vic.gov.au/publications/20140806-Public-Transport/20140806-Public-Transport.html>

¹¹ Currie, Graham; Delbosc (2011). *Invicta Intermodal Coordination Study*, ITS Monash.

8.2 List below the sources of data you use to track changes to the timetables of these other operators across all modes. If you are unsure, consider ways in which you could access this data, and list them below.

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Coordination Principles

- Consider all timetables as part of an integrated network
- Optimised coordination requires a highly iterative process through all parts of the interrelated scheduling tasks
- Develop timetable patterns with good coordination and high levels of efficiency
- Develop patterns for blocking/shift-building in that pattern
- Consider all aspects of timetable quality while developing patterns

How familiar are you with each of the timetables for the services and operators listed above?

Intermodal Coordination

“Balancing the needs of transferring/non-transferring passengers while maintaining overall quality and efficiency”

In [section 6](#) *Timetabling for Quality* we highlighted that implications for customers should always be a number one priority. Part of this understanding is knowing what directions your customers are travelling at what times, and where they are seeking to be at the end of their journeys (not just at the end of their trip with you).

8.3 Consider the customers in your region / area. List below the following considerations:

- Where are the majority likely to be going at different points in the day?
- What is the ultimate destination of your passengers (not just where they get off your buses)?
- What are the local amenities that need to be accessed on different days and times?
- Are they likely to be transferring to or from other modes of transport?

** Examples*

Event	Location / Direction	Day(s)	Times	Transfer?
<i>* Market Night</i>	<i>Whitehorse Shopping Village</i>	<i>Thursdays</i>	<i>5pm – 8:30pm</i>	<i>No</i>
<i>* Commute to City</i>	<i>Heading west towards Whitehorse Train Station</i>	<i>Weekdays</i>	<i>6am – 8:15am</i>	<i>Yes</i>

8.4 List below the percentage of your customers that will need to transfer to another mode of transport by time of day and by direction.


	Weekday Peak	Weekday off-peak	Saturday	Sunday
Mornings				
Afternoon				
Evenings				
Other				

In balancing the needs of different passengers, the exercises [8.1](#), [8.2](#), [8.3](#) and [8.4](#) above are here to help you think about the following objectives you should be meeting when scheduling for intermodal coordination:


- Defining connectivity requirements and parameters
- Defining a service to meet the needs of passengers
- Understanding demand and tidal passenger flows
- Understanding operations and demand patterns of both modes
- Creating a solution that can succeed in operation

Knowing the answers to [8.1](#), [8.2](#) and [8.3](#) will help you reduce some of the perceived penalties from customers outlined in the research above, by being able to harmonise your headways. Harmonising headways can provide immediate benefits.

Route	Frequencies - October 2014			
	Peak	Off Peak	Saturday	Sunday
100	40	40	80	
101	35	40	80	
102				60
103				
104				
105				
106	35	50	55	
107	30	40	60	
108	30	30	60	60
109	20	30	60	60
110	30	45	60	
111	30	45	60	
112				
113	25	30	60	60
118	25	30	60	60



Train is 30 minutes



Train is 40 minutes

Figure 4. Harmonised & non-harmonised headways.

You should expand on this using a simple program such as Excel, by plotting various operators, and their schedules in a spreadsheet. Harmonising headways should also include allowance for walk time between modes. For a bus rail transfer of 130 metres, it will take passengers 4 – 16 minutes¹². Your schedules should allow sufficient time for both connections, and for your customers to walk between your services and the pickups for these. However you should avoid excessive time, allowing for 'the worst case', as it penalises all passengers on a daily basis. Balancing these trade offs requires careful consideration.

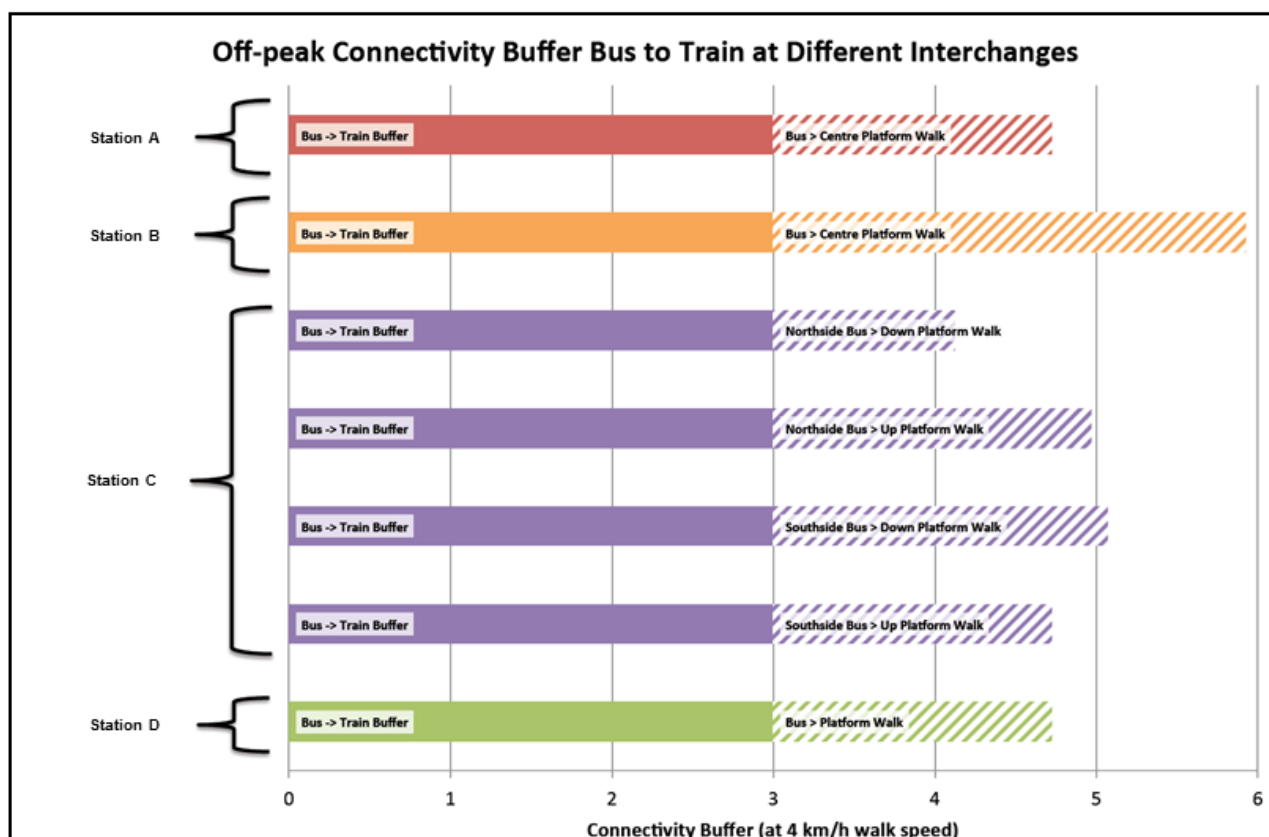
¹² Currie, Graham; Delbosc (2011). *Invicta Intermodal Coordination Study*, ITS Monash.

8.5 List below the railway stations (and other major transfer points if any) serviced by your routes/stops and the walk time between the various platforms at these stations during off peak¹³.

* Examples

Station	Platform Location	Platform	Walk time
* Whitehorse Station	Northside	Down Platform Walk	4.2 mins
* Whitehorse Station	Northside	Up Platform Walk	4.9 mins
* Whitehorse Station	Southside	Down Platform Walk	5.1 mins
* Whitehorse Station	Southside	Up Platform Walk	4.7 mins

Once you are aware of these, you can plot them to provide a graphical representation as per the graph below.



¹³ This process should be repeated for peak operation also.

Another important facet of coordination in networks is knowing the variability of the providers in your network. What data is publicly available and what do you collect? By knowing how far trains and other intermodal transport tends to deviate from schedules, you can at least set targets to meet connections.

Consider the data collected for [figure 6](#). If you wanted to meet the service at Station D 85% of the time you would need a 7 minute window (3 ½ minutes on either side of arrival) plus walk time to the station.

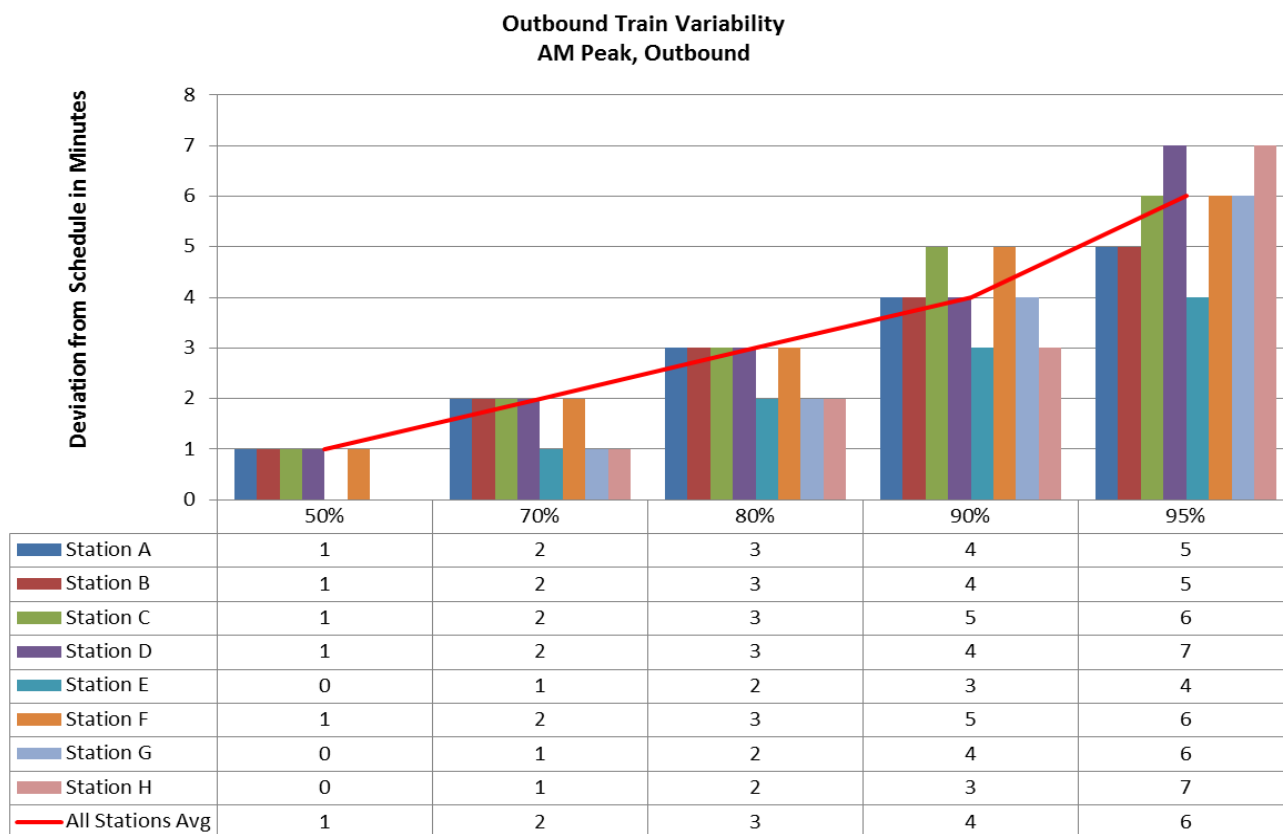


Figure 6. Hypothetical Outbound Train Variability

Intramodal Coordination

The principles for intramodal coordination are essentially the same as they are for intermodal. These are:

- Harmonised headways
- Build detailed understanding of reliability and walk times
- Set priorities based on passenger needs
- Build integrated timetables to maximise coordination while improving efficiency
- Objectively measure results

[Appendix 2](#) replicates the tables used in exercises [8.3](#), [8.4](#) and [8.5](#) to be used in planning intramodal coordination.

Differences in Intramodal Coordination

While the processes of intramodal and intermodal coordination are similar, the key differences are:

- Having to coordinate with other bus operators
- There is a greater likelihood of to have more low frequency services
- It can be less clear what direction people may want to connect to

Additionally, operators should be seeking to offset routes of other operators (as well as their own) on the same corridor, such that if there are two trips every hour, then there should be a 30 minute headway between buses.

Evaluating Good Connectivity

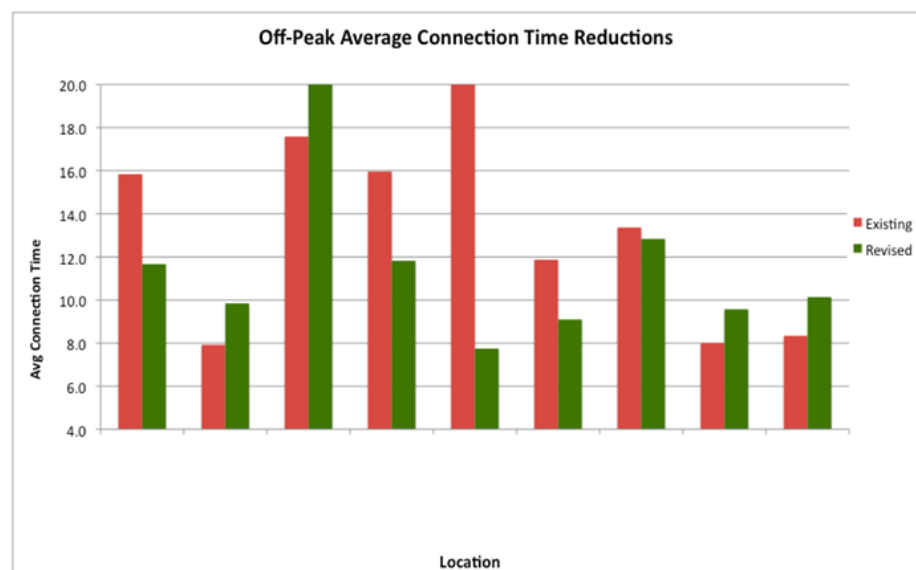
At this stage you have an idea of what data you should be collecting, and what allowances should be considered in connectivity.

Considering [figure 6](#), how do we know what is ‘good connectivity’? Should we be aiming for 80%, 85%, 90%? Beyond any contractual arrangements that you may have with regulators, there is no definition of “good”. This should be balanced against measurable objectives for your business. Look back to the objectives in [5.1](#). Is having good connectivity one of these, or does it relate to another broader objective? In [section 9 Performance Measurement](#) we will take the objectives from [5.1](#) and make these quantifiable by setting specific measures we use to measure the success of our scheduling efforts.

While the definition of “good” for your business will be based on the specific and quantifiable measures you set for yourself, there is a general guide which can be followed. In [figure 6](#) if a schedule only allows 2 minute leeway (scheduled too ‘tight’), you will meet the service on average 50% of the time, but not wait when you do meet the service. On the other end of the spectrum, you can meet the connecting service 95% of the time, but will always be waiting between 8 and 14 minutes. A study by Monash ITS¹⁴ shows that the ideal wait time lies between the minimum and maximum time.

By setting operating parameters before you evaluate your performance, you have an objective measure of success.

While not common practice, it would be good practice to graph your measurement data. Being able to see your performance before and after you apply changes to your average connection time can help demonstrate to regulators, customers and / or staff that your business is performing against set measures.



¹⁴ Currie, Graham; Delbosc (2011). *Invicta Intermodal Coordination Study*, ITS Monash.

9. Performance Measurement

In [Section 5](#) you plotted out your objectives in scheduling. Measurement is a key component in knowing whether or not you are achieving your objectives. Not only does this allow for identification of what areas are doing well, and what needs improvement, but it also allows for demonstration to regulators that we are able to achieve demonstrable outcomes.

Review your responses to exercise [5.1](#). Through this workbook we have addressed the key components in contemporary scheduling:

- Quality
- Reliability
- Efficiency
- Networks (intermodal and intramodal)

When setting these objectives they should be clear, measurable, and above all they should make sense (never fail to apply the 'common sense' test).

How do your responses align to these components? If you need extra objectives, or to apply changes, write them down below.

9.1 Additional Objectives

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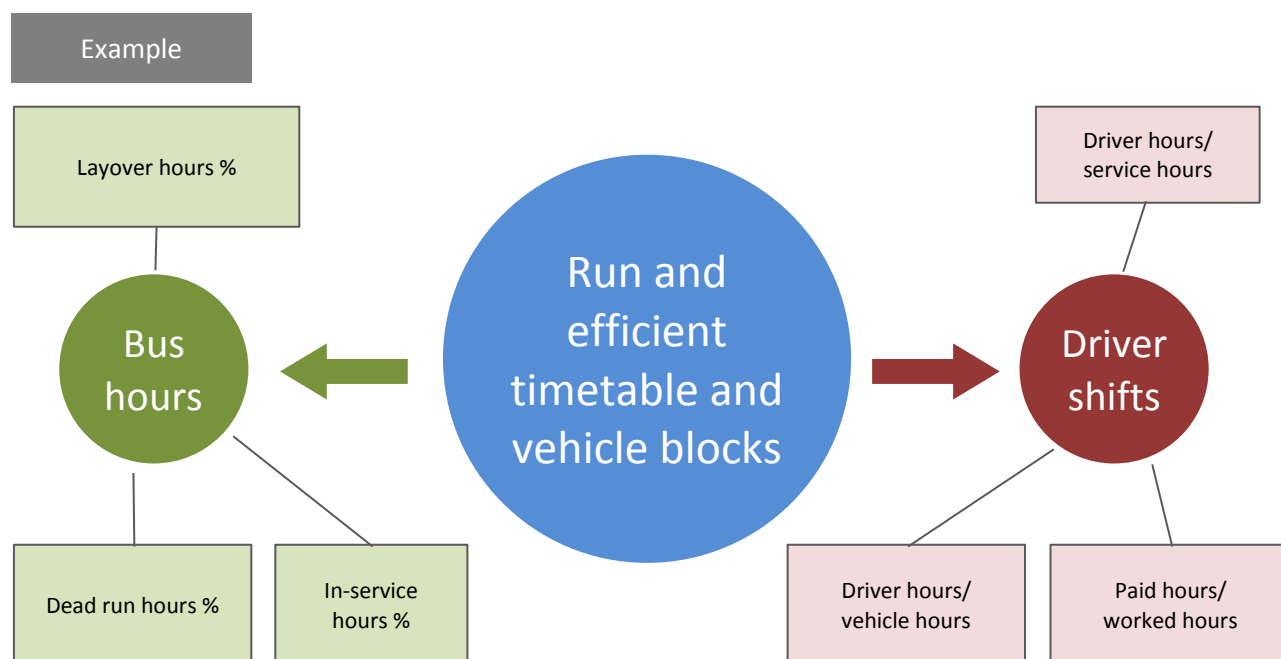
.....

While it is often rare to find standardised KPIs used in scheduling, most information can be objectively compared in some way. It is important for operators to undertake this process themselves, as KPIs are not necessarily transferrable between operators.

In the second workbook in this series *Performance Measurement* we outlined a four-step process for identifying performance measures. In this context, your objectives can be thought of as your Critical Success Factors. Following the same process, you can break down your objectives into multiple aspects, and then brainstorm performance measures.

Review your responses to [5.1](#), and any from [9.1](#), and review the process from *Performance Measurement* again. Pick one of your objectives, and brainstorm some measures in the space provided in 9.2 below.

Try to develop a range of specific measures so that you have a choice in deciding which measure reflects the success of the objective.



9.2 Set Measurement of Objectives

Once measures have been set, you can use the example / template included in [Appendix Two](#) of this workbook to compare results before and after review and refinement of schedules.

10. Tools for Timetabling

While larger metropolitan operators tend to use sophisticated proprietary systems for scheduling to handle the sheer volume of complexity of their data, the argument for computerisation for smaller operators may be less clear.

Even smaller operators will likely be using software such as Excel for reporting to regulators, computerising can assist in the end to end process of scheduling, encompassing efficiency, speed and integration.

The reasons for computerising a metropolitan or regional schedule are the same and include:

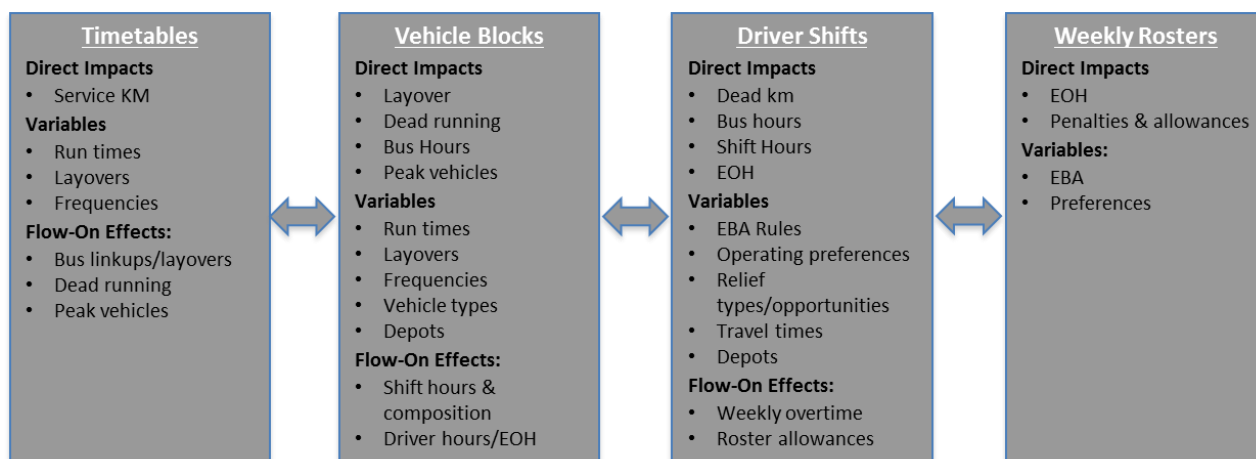
- The problem is complex;
- The need for immediate and detailed information, from regulators to passengers, is extensive;
- It reduces the resources required to complete tasks, and
- It creates the possibility for linking to various other internal, and external systems (bus tracker, payroll and dispatch software).

However *computerisation* doesn't necessarily mean *automation*. While software is available, crew scheduling is generally too complex for a computer to genuinely provide the 'best' or 'optimal' solution, and is often an integrated task with vehicle scheduling. Timetabling development can also be automated, but has potentially unlimited iterations, and can be difficult to evaluate any value judgements an operator has made through the process.

"The complexity of most scheduling problems is beyond the capability for programs to automatically solve or fully optimise"

Consider figure 7. The array of interacting data and information can be overwhelming.

Figure 7. Interplay between various elements of schedules.



There is a range of software available for managing each of these elements. Finding the balance between these elements using complex software could mean having to generate anywhere from 50 – 100 solutions to get the 'best' one.

Powerful, yet 'basic' tools, such as Excel, have a number of advantages. They are abundantly available, relatively cheap, and easy to use which cuts down on learning curves for operators and their staff in inputting data and creating reports.

Additionally, off the shelf products have their inputs and outputs, but the processing in between is not brought to the surface. These solutions have a wide variety of assumptions which users are, more often than not, unaware of or understand. When working with programs such as Excel:

- Data sources can be seen by using formulas which link to assumptions;
- Assumptions can easily be outlined and adjusted;
- The logic of outputs is clear and can be followed through, and
- Tasks can be integrated

With each of these elements brought to the surface, the outputs can be assessed for their quality and be clearly understood. This gives operators the power to adjust these elements to best achieve each of their objectives.

11. Bringing it Together

Throughout this workbook, we have guided readers through the various considerations required in contemporary scheduling. Given the vast components of scheduling, it would be near impossible to get it right the first time around. As discussed in [section 10](#), *Tools for Timetabling*, the process of setting schedules and timetables is iterative, and is not a ‘set and forget’ process. Each of the exercises were designed to give an opportunity to explicitly outline and test the assumptions of operators, and act as a starting point for scheduling.

Below we outline the step by step process an operator should go through in setting their schedules.

** indicates an iterative process*

1. Collate and summarise scheduling rules

In sections [5](#) and [6](#) we discussed the difference between hard and soft rules. The items below reflect ‘hard’ rules.

- 1.1 Labour agreements
- 1.2 Legislation (such as driver fatigue)
- 1.3 Fleet

2. Record existing solutions

In [section 4](#) we discuss gathering data for the scheduling process, and in [section 10](#) the tools available. For whatever software or program you decide to use, the information below will act as a starting point for developing your scheduling solutions.

- 2.1 Enter route definitions
- 2.2 Enter current timetables
- 2.3 Enter current blocks and shifts
- 2.4 Define the rules, parameters (and assumptions)
- 2.5 Summarise existing solutions

3. Develop new timetables

Steps 3 and 4 in the process is starting to develop new timetables and scheduling solutions. It is an iterative process, whereby you need to review, refine, and revise over and over until an optimal solution is met. Optimal will be based on your stated objectives, and how well they balance the Key Components of Scheduling (Quality – [section 6](#), Reliability & Efficiency – [section 7](#), and Coordination for Networks – [section 8](#)).

- 3.1 Update route definitions
- 3.2 Create proposed new timetables
- 3.3 Review and analyse
- 3.4 Revise and update*

4. Develop Scheduling Solutions

- 4.1 Establish blocking rules
- 4.2 Establish runcutting rules
- 4.3 Generate blocking solutions*
- 4.4 Review, refine, revise blocking*
- 4.5 Generate run cut solutions*
- 4.6 Review, refine, revise run cuts*
- 4.7 Generate draft period rosters*
- 4.8 Review, refine, revise period rosters*
- 4.9 Final scheduling solutions*

5. Produce operating outputs

In [section 9](#) we discuss performance measurement. Once performance measures have been set, they should be reported against so that operators and senior management can see how their performance is tracking. Monitoring and reporting also allows for incremental review and adjustment of schedules and timetables where needed.

- 5.1 Agree outputs and formats
- 5.2 Produce reports and outputs

Appendix One – Suggested Solutions

6.2 What would be some of the challenges a customer would face with a schedule like the one in [Table 1](#)? How can they be resolved?

	3	16	23	1	18	18	5	16
A	B	C	B	A	B	C	A	B
7:52	7:55	8:11	8:34	8:35	8:53	9:11	9:16	9:32
8:03	8:05	8:21	8:44	8:46	9:03	9:21	9:26	9:42
8:13	8:17	8:32	8:56	8:56	9:14	9:32	9:37	9:53
8:20	8:24	8:39	9:03	9:03	9:21	9:39	9:44	10:00
		8:45			9:27			10:06
		8:50			9:32			10:11
8:31				9:14			9:53	
	8:35	8:59	9:15		9:41	9:50		10:20
8:37				9:20			9:59	
8:43				9:26			10:05	
9:02	9:00	9:24	9:40	9:45	10:05	10:15	10:24	10:45
70 Mins			70 Mins			68 Mins		

Problems
Inconsistent or uneven headways (as demonstrated between routes on top of table)
Inconsistent running times (as seen in the blue box)
Non-memory (difficult to remember) headways (as highlighted)
Inconsistent running times (as demonstrated along the bottom)

Suggested solutions

Please note that there are a number of ways that the timetable above could be adjusted, however the one below is a suggested solution.

10 10 10 10 10 10 20							20 20 20 20 20					Off Peak
B	C	A	B	C	A	B	C	A	B	C	A	B
7:55	8:05	8:15	8:25	8:35	8:45	8:55	9:15	9:35	9:55	10:15	10:35	10:55
8:05	8:15	8:25	8:35	8:45	8:55	9:05	9:25	9:45	10:05	10:25	10:45	11:05
8:16	8:26	8:36	8:46	8:56	9:06	9:16	9:36	9:56	10:16	10:36	10:56	11:16
8:23	8:33	8:43	8:53	9:03	9:13	9:23	9:43	10:03	10:23	10:43	11:03	11:23
	8:39			9:09			9:49			10:49		
	8:44			9:14			9:54			10:54		
		8:53			9:23			10:13			11:13	
8:35	8:53		9:05	9:23		9:35	10:03		10:35	11:03		11:35
		8:58			9:28			10:18			11:18	
		9:06			9:36			10:26			11:26	
9:00	9:18	9:25	9:30	9:48	9:55	10:00	10:28	10:45	11:00	11:28	11:45	12:00
65	73	70	65	73	70	65	73	70	65	73	70	65
Mins	Mins	Mins	Mins	Mins	Mins	Mins	Mins	Mins	Mins	Mins	Mins	Mins

6.3 In reviewing the schedule in [Table 1](#), assume the operator who created it had very specific reasons for why it was like this. List reasons why an operator may have felt compelled to set their blocks like this.

- To meet local or tidal flow demands
- To ensure services to local events / amenities are met
- To intersect with inter/intramodal transport

6.4 What are some of the issues that might cause dissatisfaction for drivers in this schedule? How can they be resolved?

Problems	Resolutions
Not having sufficient meal times and breaks scheduled	As per table above
Some stops are scheduled at the same time / unrealistic	As per table above
Uneven spread of timetable gaps can create confusion for drivers and perhaps result in frustrated customers	As per table above

6.6 Review your answers to 6.2, 6.4 and 6.5. When considering issues identified, were there similarities between solutions? If not, consider ways you could change operations or schedules to address these problems. Consider how these fit to your objectives in 5.1.

Issues for customers and issues for staff are often linked, or can have flow on effects for drivers. Timetable issues can cause a variety of negative responses from customers from frustration to anxiety¹⁵. In a practical sense this can result in drivers having to deal with customers that are unhappy with a schedule that is out of their control. By scheduling using clockface headways and setting even looking schedules, these will be easier for drivers and customers to remember, and may result in a more pleasant experience for everyone.

¹⁵ Visit <http://www.eng.monash.edu.au/civil/research/centres/its/> for research on passenger attitudes.

7.2 Consider the following scenario.

An operator in a regional area has been operating on contracts in their region for over 20 years. This operator is heavily tied up in the administration of running the business, and no longer conducts runs himself. Despite this, and recent development and growth in the region, the operator feels pretty confident with their knowledge of the area.

The current running times have been the same for roughly 10 years, and are closely based on times for previous contracts. When first setting running times for routes, the operator has made sure that there is sufficient time to cover both runs and layover time at the multiple interchanges along routes. Periodically drivers will report congestion on routes leading to schedules consistently running behind. To deal with this the operator surveys a few of the more experienced drivers in the business and takes an average of their estimates of extra time required and adjusts the schedules accordingly. In general, except for these adjustments, the operator finds they are meeting on-time performance.

The operator is now looking to future contracts. The operator, like most other operators today, is facing pressure to reduce costs from contestable processes, as well as seeking to lower costs to achieve a better return on their investment in the business. They are not sure where to start in finding efficiencies for the business, but suspect that there is room to optimise run times which will help increase margins.

Outline some points below about how the operator might start to look at runs to gain efficiencies, or suggest some areas which might help the operator optimise running times based on the information provided in the scenario. How does this scenario compare to the way you plan and schedule your running times?

1. The operator in the scenario above has likely not been on runs for a number of years. While experience speaks for a lot of an operator's business, by occasionally experiencing runs operators gain a quick and practical understanding of the issues of drivers and customers. These can be works in the area, new buildings or centres that need to be accessed, or changes to local infrastructure.
2. This operator's run times are based on those set a decade ago. It is unlikely that customer needs, traffic conditions and patronage are going to remain static over this period. A systematic review of schedules should be conducted regularly. Again, experiencing runs can be a quick way to gain insight.
3. There are multiple interchanges along this route. It is not uncommon for operators to increase the use of interchanges and layovers to solve scheduling inconsistencies. This can actually be the cause of congestion through having buses laying over for extended periods, and taking up room in bays. The operator above has not considered structuring their operations in a way that reduces congestion similar to the suggested routes in [figure 3](#) in section 7. This can:
 - be an alternative to adjusting routes by averaging feedback from drivers (although feedback from drivers is an important part of scheduling, and should not be ignored);
 - reduce the need to dispatch more buses while others are parked in interchanges, adding to efficiency, and
 - reduce deadhead hours/kilometres by not having buses navigating congested interchange points.
4. The operator is meeting on-time performance, but this does not necessarily mean that they are executing an efficient operational plan. Reliability is important, but should not be a standalone indicator of a successful timetable.

Appendix Two – Tables for Intramodal Coordination

8.3 Consider the customers in your region / area. List below the following considerations:

- Where are the majority likely to be going at different points in the day?
- What is the ultimate destination of your passengers (not just where they get off your buses)?
- What are the local amenities that need to be accessed on different days and times?
- Are they likely to be transferring to or from other operators?

Event	Location / Direction	Day(s)	Times	Transfer?

8.4 List below the percentage of your customers that will need to transfer to another operator/ route by time of day and by direction.

	Weekday Peak	Weekday off-peak	Saturday	Sunday
Morning Peak				
Afternoon				
Evening Peak				
Other				

Appendix Three – Summary Comparison Tool

Please see the Microsoft Excel spreadsheet attached to this workbook: *Generic Cost Template*. This tool provides some simple calculations that can be used to measure your scheduling solutions. The indicators are not necessarily applicable from one operator to another, but are invaluable in assessing the impacts of scheduling or operational changes from one solution to the next – for the same operator.