Presented by Brian Simmonite at the Ninth JCT Traffic Signals Symposium 9th Sept. 2004

Using Phase Timings in a TRANSYT network

Background

Since the mid 1980's with the introduction of microprocessor signal controllers and LINSIG, the use of phases and the calculation of phase Intergreens and minimums has become the norm in the design of traffic signal junctions. Whilst phases are an integral part of LINSIG they have never been part of TRANSYT and as such anyone modelling signalled junctions on a network has had to convert phase based timings into a stage based model.

In 1997 JCT Consultancy, a specialist traffic signal design consultancy and software developer independent from the Transport Research Laboratory (TRL) launched TranEd. TranEd is a graphical interface for TRANSYT running on Microsoft® Windows and provides a series of graphical tools to help users prepare and analyse traffic signal networks in TRANSYT. A paper looking ahead to the launch of TranEd was presented at the 2003 JCT Symposium.

This paper looks at the problems faced when making phase to stage conversions and how TranEd Version 2 was developed to help with these problems.

Modelling Signals in TRANSYT

In TRANSYT signals are based around a strict stage based model using 'lags' (broadly analogous to modern phase delays) to implement the effects of phase Intergreens and phase delays present in modern controller design. The best way of comparing it to modern methods is to envisage designing Interstages using only phase delays with no Intergreens. Clearly this makes working with modern controller data quite difficult as the data from controller specification sheets has to be manually massaged to convert from Interstage structures using both Intergreens and phase delays to one based on just lags. This process requires completion for each Interstage, which for large complex junctions with many stages could be quite onerous. Certainly for junctions with a significant number of parallel pedestrian phases, this task is tedious and it is not surprising that many TRANSYT files are prepared by making a guesstimate of the link lags and minimum stage durations. This has lead to an inconsistency in the accuracy of models presented for a typical signal controlled junction when on the one hand using LINSIG for isolated junctions and TRANSYT for networks. Additionally if changes were made to Intergreens a considerable amount of manual reworking is often necessary with many opportunities for manual errors to be introduced.

A further difficulty in TRANSYT is the work involved to experiment with alternative stage arrangements. For example, to swap two stages requires not only recoding of the stage information on the node, but also recoding each link involved to change both its start and end stages and its lags, to reflect the new stage structure. Again this is a prime opportunity for manual errors to be introduced.

Modelling Signals in TranEd Version 2

The lag based approach of constructing Interstages used in TRANSYT and TranEd Version 1 has been replaced with a completely new model based on a simplified version of the LINSIG model. TranEd Version 2, which was released earlier this year, allows the user to enter link lags as link Intergreens in a very similar way to phase Intergreens, and also enables link minimums to be entered which can be used to calculate stage minimum durations.

Use of the full phase based model from LINSIG was considered, however it was not chosen because feedback from users generally indicated many TRANSYT users did not require, or desire, the level of detail needed in LINSIG. Instead a simplified model was developed that introduces the concepts of link Intergreens and link delays. These are analogous to phase Intergreens and phase delays in LINSIG but relate to TRANSYT links rather than phases. This model allows users to directly enter and work with Intergreen and link delay information in a similar manner to LINSIG. On running TRANSYT, TranEd processes the Intergreens to derive the start and end lags necessary to replicate the designed Interstage structures and implements these in TRANSYT. Backwards compatibility with the traditional TRANSYT approach is easy to implement – just ignore the new Intergreens and use link delays alone!

Conversion of Phase Intergreens to Link Intergreens in TranEd V2

TranEd has been designed to work with link to link Intergreens as well as the conventional 'TRANSYT' style link lags. Consider the example in Fig 1 which shows a simple two stage junction. phases A and C run together in stage 1 and phase B which is conflicting runs in stage 2. When moving from stage 1 to 2, there are two Intergreens to be considered; phase A to B which is equal to 5 seconds and phase C to B which is equal to 9 seconds. The resulting Interstage (Fig 2) is equal to 9 seconds.

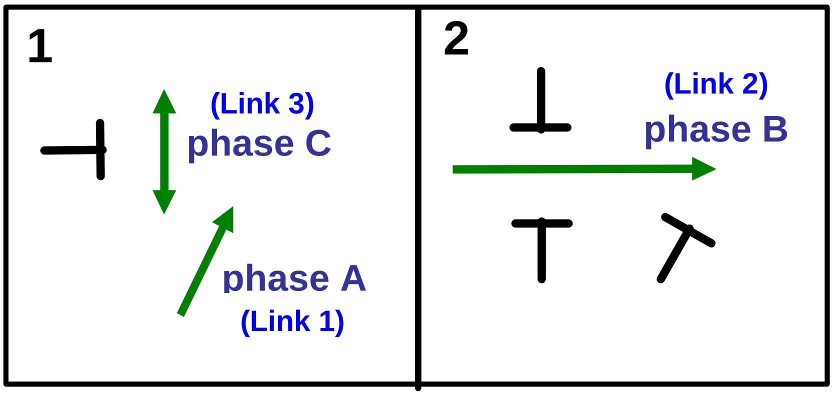


Fig 1 – Two stage Example

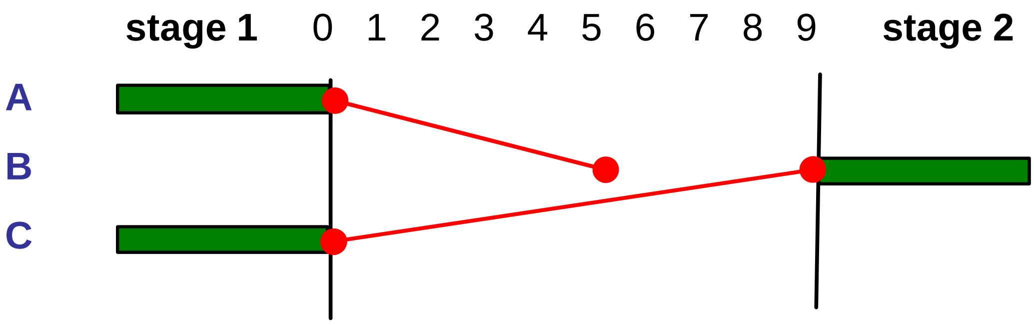


Fig 2 – Interstage Timings

In TRANSYT, the link representing the movement of traffic on phase B (link 2) would have a lag equal to 9 seconds. This has to be worked out manually from the two phase Intergreens. In TranEd, the user would specify the phase Intergreens as Link Intergreens (Fig 3).

The Link Intergreens are worked out directly from the phase Intergreens; each link in TranEd effectively mapped to a controlling phase. However, if the method is to work correctly, it is important that pedestrians and indeed any other sort of phase which can impact on the Intergreen matrix are modelled as links in TranEd. Hence phase C which is a pedestrian phase is represented by Link 3.

Links	Phases
1	A
2	B
3	C

	A	B	C
A		5	-
B	5		5
C	-	9	

	1	2	3
1		5	-
2	5		5
3	-	9	

Conversion **phase Intergreens** **Link Intergreens**

Fig 3 – Transferring Phase Intergreens to Link Intergreens

The transfer of information from phase timings into Link timings (Fig 3) is relatively straightforward and up until now has to be carried out manually. Whilst this is much easier than the conventional method of working out link lags, it is still time consuming and can still lead to errors.

TranEd – Phase Intergreen Conversion Tool

To speed up the process of transferring Intergreens from phases to Links and to reduce errors, a Converter Tool has been written for TranEd. If Intergreens are to be calculated initially on a link to link basis, then the Converter Tool will not be required. However, there are many examples where a TRANSYT model is prepared from LINSIG models or directly from controller specifications which are both phase based. In any event, a design will need phase Intergreens to be calculated for the controller configuration and it makes sense to carry out these calculations first. Currently, the phase Converter requires phase Intergreens to be entered manually but this will change when a data link between LINSIG and the Converter Tool is added into a future update of LINSIG.

The Converter Tool functions as a specific view in TranEd and can be divided into three elements. A phase Intergreen matrix as already discussed, a table which allows each link to be cross referenced with a controlling phase and a link Intergreen matrix which shows what the link Intergreens would be if the conversion is activated (Fig 4).

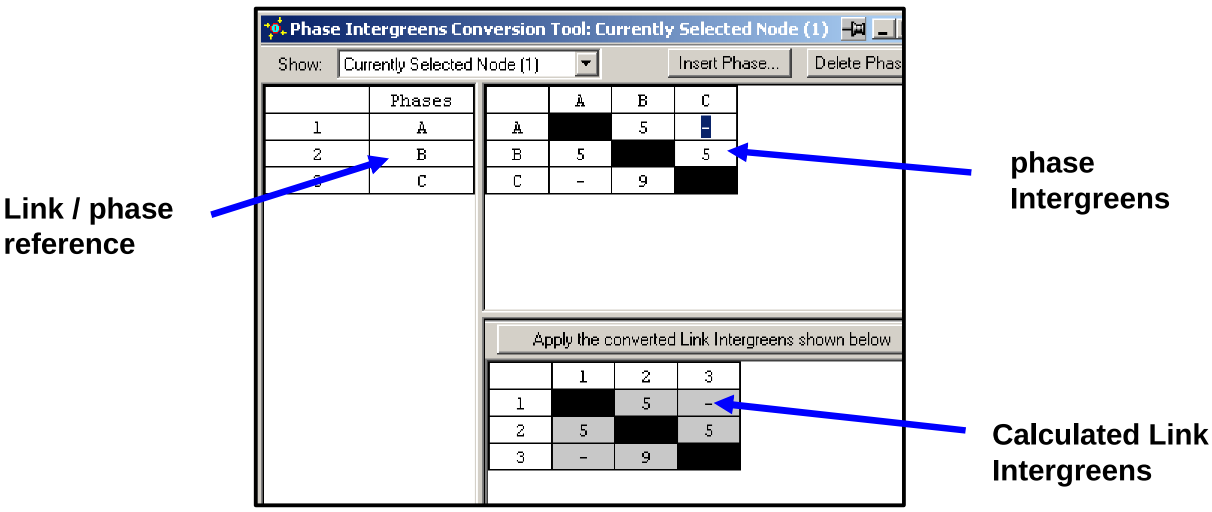


Fig 4 – TranEd Phase Converter Tool

For the most part, this process of mapping links to phases and specifying phase Intergreens is relatively easy. The only complications arise when dealing with ‘arrow’ phases such as filters and indicative arrows. Skilled TRANSYT users will be well versed in how to apply TRANSYT logic to this rather unique form of signalling used in the UK. The difficulties arise because TRANSYT and consequently TranEd have no direct understanding of a phase or indeed how a link can be controlled by two phases. This is explained carefully with the following two examples:-

(a) Filter Arrows

Consider the signal arrangement below (Fig 5), which shows a full green phase (D) and a left filter phase (F). Traffic turning left will be controlled initially by the Filter (phase F) then by the full green (phase D). Modelling this scenario in LINSIG requires the user to specify that the left turn traffic movement is controlled by phases F and D. In TRANSYT the user will need to specify the stage in which phase F runs and the stage in which phase D runs. In TranEd, when using the phase Converter, the situation will be similar to LINSIG in that the user simply specifies that the left turn traffic movement is referenced to both phase F and D.

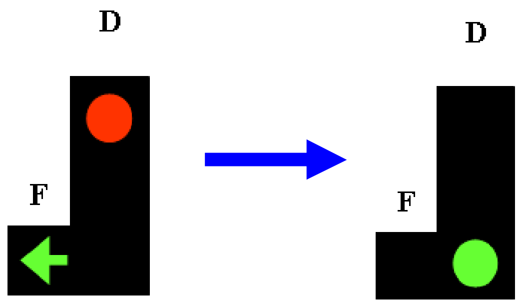


Fig 5 – Use of Filter Arrows

(b) Indicative Arrows

Consider the signal arrangement shown below (Fig 6), which shows a full green phase (A) and an Indicative Arrow phase (E). Traffic turning right will be controlled initially by the full green (phase A) and the movement will be opposed. When the opposing traffic is stopped, right of way is given to the right turn by use of the Indicative Arrow (phase E). Modelling this scenario in LINSIG requires the user to specify that the right turning traffic is controlled by phases A and E. In TRANSYT the user will need to specify the stages in which traffic can turn right. In TranEd, when using the phase Converter, the situation is again similar to LINSIG in that the user simply specifies that the right turning traffic is referenced to both phases A and E.

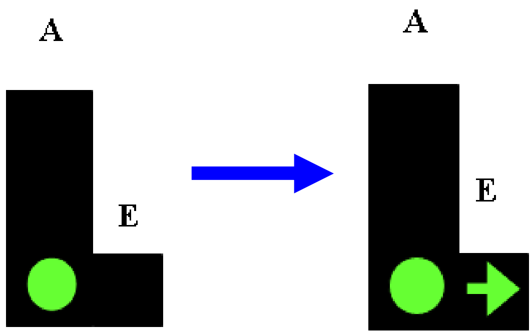


Fig 6 – Use of an Indicative Arrow

Conversion Logic

The logic used in the conversion is straightforward and there are three scenarios to consider.

If a pair of links are matched to Intergreens which are all non conflicting, then the conversion tool will select the links to be also non conflicting.

If a pair of links are matched to Intergreens which are all conflicting, then the conversion tool will select the links to be also conflicting using the highest Intergreen (for safety reasons). In reality, if the Intergreens have been worked out correctly, these values should be the same.

If a pair of links are matched to Intergreens in which at least one Intergreen is non conflicting (n/c), then the conversion tool will select the links to be also not conflicting on the basis that the least onerous phase will be controlling the link. This is explained more fully in the example below.

Worked Example in using the phase Converter Tool

To explain the use of the phase Converter Tool, and the logic behind it, consider the example below which represents a simple crossroads with parallel pedestrian facilities. The phase structure (Fig 7) has one traffic phase per approach (A to D), an indicative arrow for right turning traffic on the main road (E), a left filter arrow for left turners out of the side road (F) and three parallel pedestrian phases (G, H and I). The phase Intergreens (Fig 8) and the stage structure (Fig 9) have all been taken from LINSIG for convenience. The stages selected for analysis run the main road (stage 1) the early cut off (stage 2) and the side road (stage 3). The Pedestrian phase H is not active in this sequence.

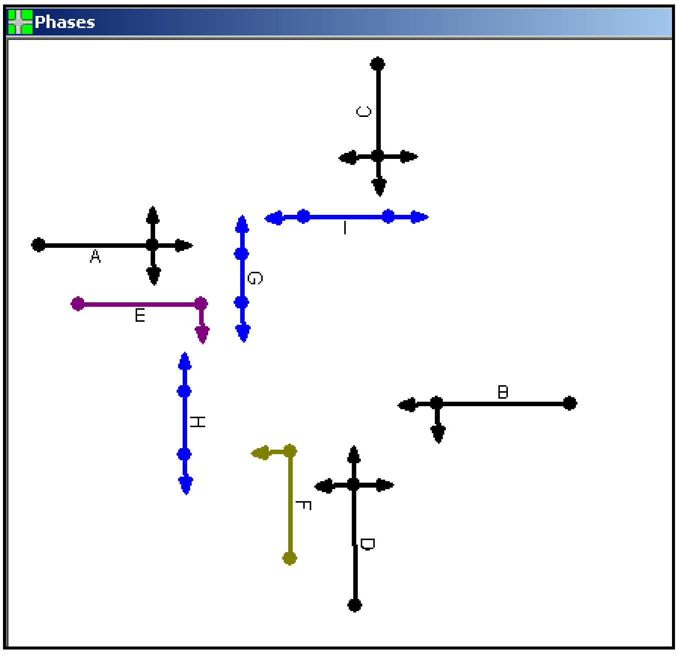


Fig 7 – Phase Structure

Intergreen Matrix

	A	B	C	D	E	F	G	H	I
A		-	7	5	-	-	5	-	-
B	-		6	7	3	7	-	8	-
C	5	6		-	5	5	-	9	5
D	6	5	-		6	-	-	7	8
E	-	5	7	5		-	5	-	-
F	-	-	-	-	-		-	-	-
G	8	-	-	-	8	-		-	-
H	-	8	8	8	-	8	-		-
I	-	-	12	12	-	-	-	-	-

Fig 8 – Phase Intergreens

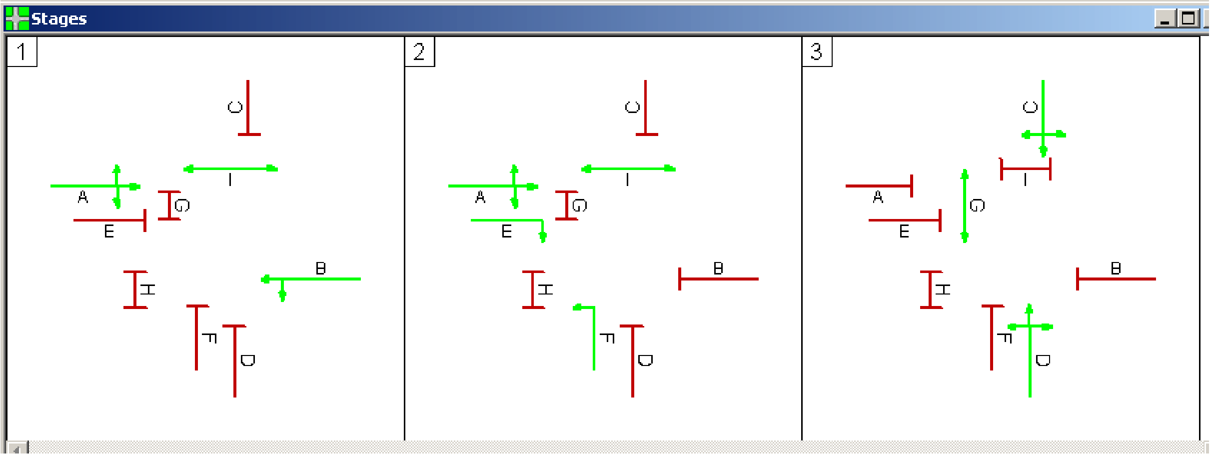


Fig 9 – Stage Structure

A TranEd model of the above junction is shown in Fig 10. In this view, the link text format has been changed to show the controlling phase(s) (above) and the link number (below). TRANSYT and indeed TranEd, only need to know when a link is receiving a 'green' signal. It does not know what type of phase is providing that green signal. However, these 'arrow' phases cannot be simply ignored because we are going to use their Intergreens to determine link Intergreens and conflicts. For example, in the case of filters it is likely that the left turn traffic movement controlled by phases F and D will have fewer conflicts than the adjacent ahead movement controlled by phase D and as such the opportunity for a green signal will be increased. In the example below, if phase F were to be ignored, then link 16 would not be green in stage 2 (Fig 11).

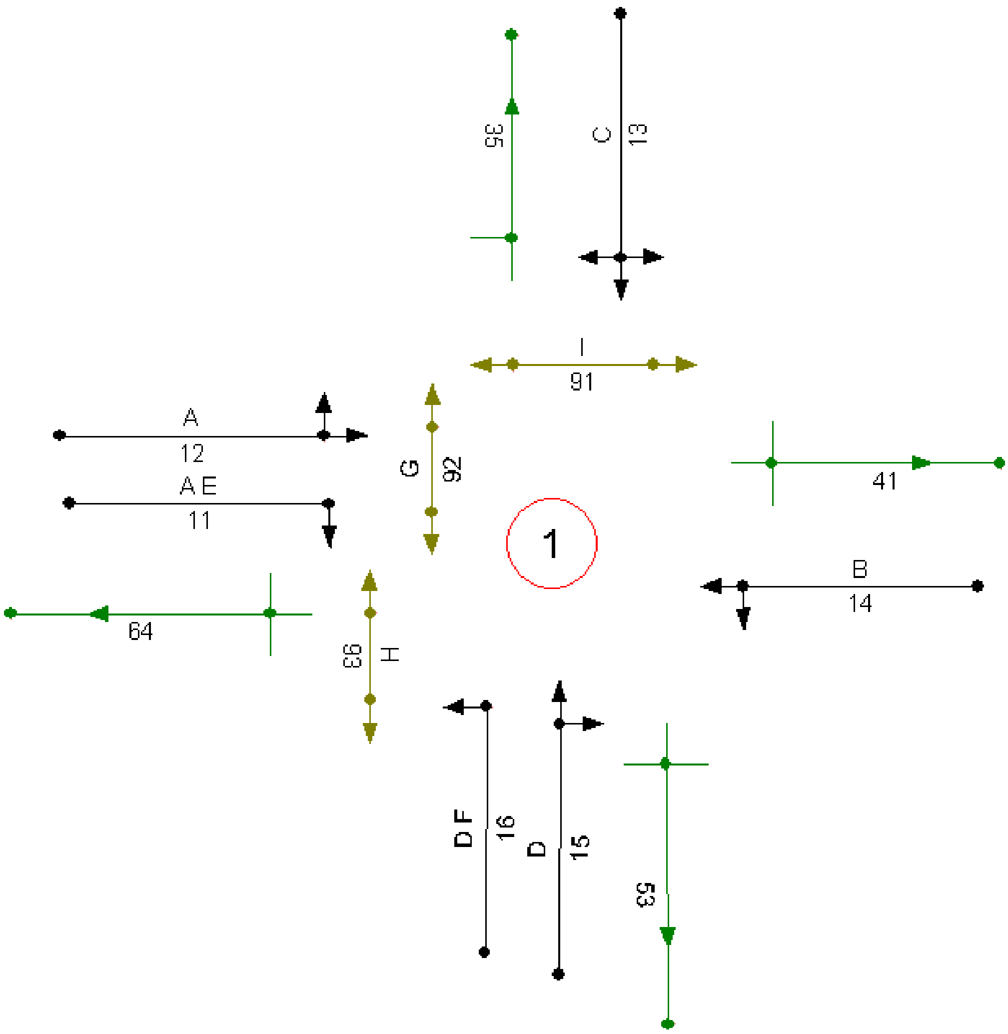


Fig 10 – Junction in TranEd Network View

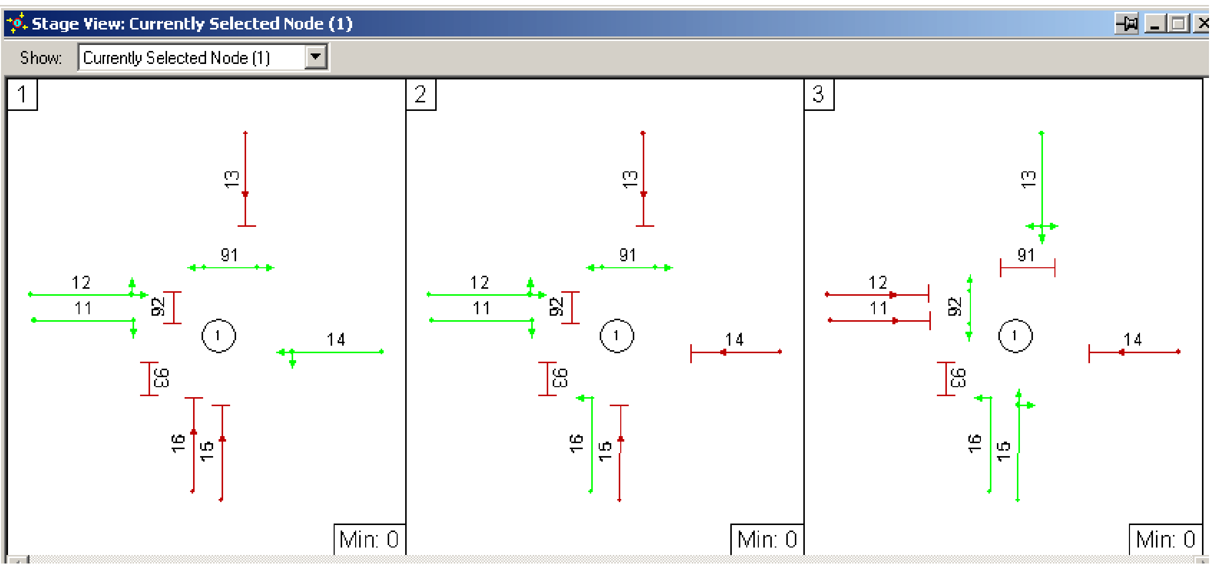


Fig 11 – Stages and Link configuration in TranEd

Entering Data into the Phase Converter Tool

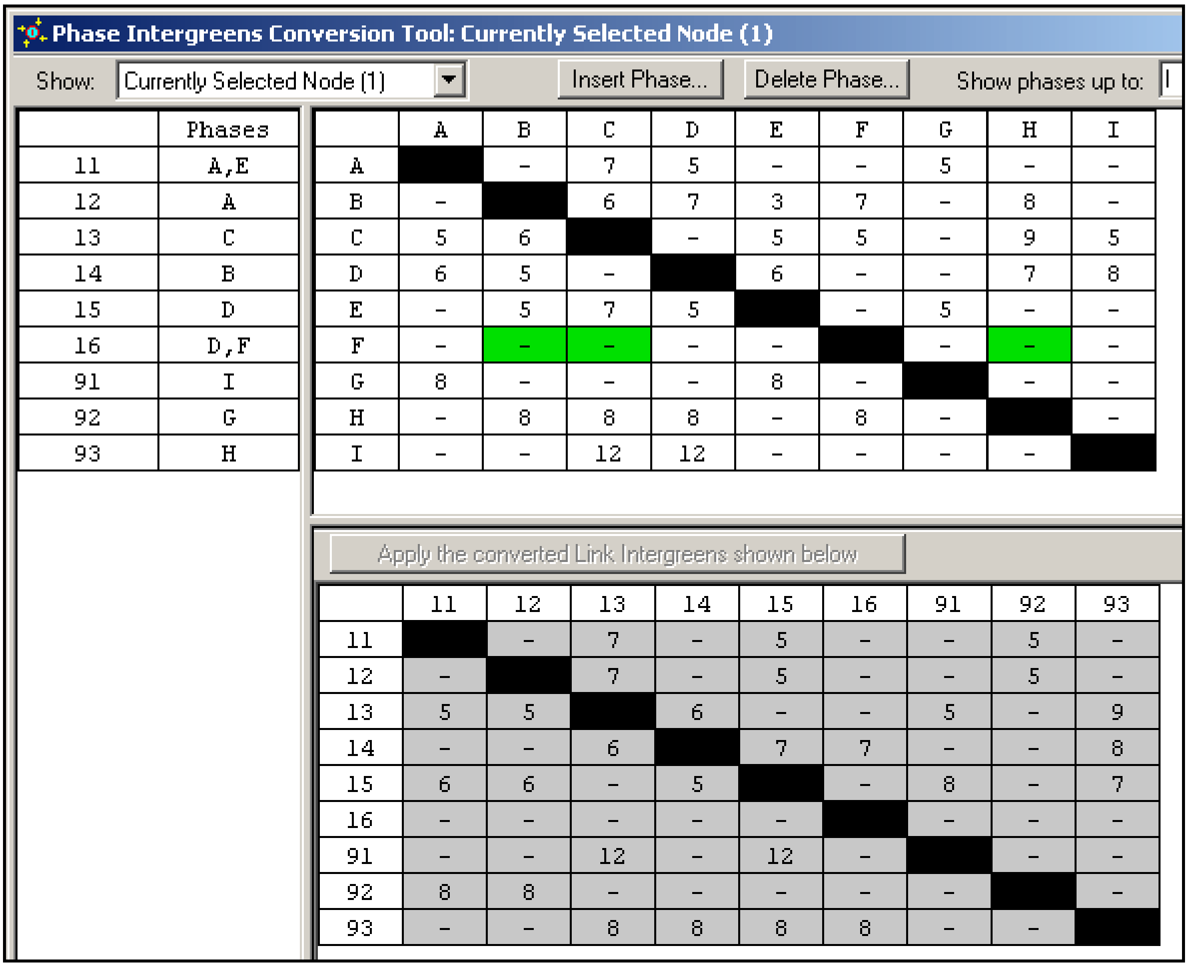
The phase Converter Tool (Fig 12) is set up to transfer the phase Intergreens (Fig 8) into Link Intergreens specified in the TranEd network (Fig 10). The right hand side of the View shows two Intergreen Tables. The top table shows the phase Intergreens which have been copied manually from the Phase Data (Fig 8). The Table below shows what the link Intergreens will be if the converted link intergreens are transferred to the TranEd model. Note that at this point the converter is not allowing any conversion to take place; you will notice that the box which says 'Apply the converted Link Intergreens shown below' is inactive.

The Converter Tool will not allow the implementation of converted Intergreens to take place under either of the following two conditions:-

(a) if the phase Intergreen matrix is not symmetrical

(b) if there are stages already constructed which would cause a conflict.

In this example, it is if the former which applies and is explained further in 'Conversion 5'. The later case is explained later under Conflict Errors preventing Transfer.



	Phases
11	A,E
12	A
13	C
14	B
15	D
16	D,F
91	I
92	G
93	H

	A	B	C	D	E	F	G	H	I
A		-	7	5	-	-	5	-	-
B	-		6	7	3	7	-	8	-
C	5	6		-	5	5	-	9	5
D	6	5	-		6	-	-	7	8
E	-	5	7	5		-	5	-	-
F	-	-	-	-	-		-	-	-
G	8	-	-	-	8	-		-	-
H	-	8	8	8	-	8	-		-
I	-	-	12	12	-	-	-	-	

	11	12	13	14	15	16	91	92	93
11		-	7	-	5	-	-	5	-
12	-		7	-	5	-	-	5	-
13	5	5		6	-	-	5	-	9
14	-	-	6		7	7	-	-	8
15	6	6	-	5		-	8	-	7
16	-	-	-	-	-		-	-	-
91	-	-	12	-	12	-		-	-
92	8	8	-	-	-	-	-		-
93	-	-	8	8	8	8	-	-	

Fig 12 – Phase Converter Tool

Conversion 1 – Link 12 to 13

Link 12 is controlled by phase A, Link 13 by phase C (Fig 4).
Hence the Intergreen from Link 12 to 13 will take the value A to C which will be 7 seconds (Fig 8). The TranEd computed link Intergreen is shown below (Fig 13).

Apply the converted Link Intergreens shown below

	11	12	13	14	15	16	91	92	93
11		–	7	–	5	–	–	5	–
12	–		7	–	5	–	–	5	–
13	5	5		6	–	–	5	–	9
14	–	–	6		7	7	–	–	8
15	6	6	–	5		–	8	–	7
16	–	–	–	–	–		–	–	–
91	–	–	12	–	12	–		–	–
92	8	8	–	–	–	–	–		–
93	–	–	8	8	8	8	–	–	

Fig 13 – Link Intergreen from 12 to 13 (not yet converted)

Conversion 2 – Link 12 to 14

Link 12 is controlled by phase A, Link 14 by phase B (Fig 10).
Hence the Intergreen from Link 12 to 14 will take the value A to B which will be n/c (non conflicting) (Fig 8). TranEd will therefore take the link Intergreen to be non conflicting by putting a dash in the cell.

Apply the converted Link Intergreens shown below

	11	12	13	14	15	16	91	92	93
11		–	7	[illegible]	5	–	–	5	–
12	–		7	–	5	–	–	5	–
13	5	5		6	–	–	5	–	9
14	–	–	6		7	7	–	–	8
15	6	6	–	5		–	8	–	7
16	–	–	–	–	–		–	–	–
91	–	–	12	–	12	–		–	–
92	8	8	–	–	–	–	–		–
93	–	–	8	8	8	8	–	–	

Fig 14 – Link Intergreen from 12 to 14 (not yet converted)

Conversion 3 – Link 11 to 14

Link 11 is controlled by phases A and E, Link 14 by phase B. phases A and B are full traffic phases whilst phase E is an indicative arrow.
Hence the Intergreens which affect these links are as follows:-

phase A to B Intergreen which is n/c
phase E to B Intergreen which is 3 seconds

Hence TranEd will compute the Intergreen from Link 11 to 14 to be n/c. In TRANSYT this is the correct scenario because Link 11 will be green at the same time as 14, irrespective of the operation of the indicative arrow (Fig 11).

Apply the converted Link Intergreens shown below

	11	12	13	14	15	16	91	92	93
11		–	7	–	5	–	–	5	–
12	–		7	–	5	–	–	5	–
13	5	5		6	–	–	5	–	9
14	–	–	6		7	7	–	–	8
15	6	6	–	5		–	8	–	7
16	–	–	–	–	–		–	–	–
91	–	–	12	–	12	–		–	–
92	8	8	–	–	–	–	–		–
93	–	–	8	8	8	8	–	–	

Fig 15 – Link Intergreen from 11 to 14 (not yet converted)

Conversion 4 – Link 16 to 11

Link 16 is controlled by phases D and F, Link 11 by phases A and E. phases A and D are full traffic phases, E is an indicative arrow and F is a left Filter. The Intergreens which affect these links are as follows:-

phase D to A Intergreen which is 6 seconds
phase D to E Intergreen which is 6 seconds
phase F to A Intergreen which is n/c
phase F to E Intergreen which is n/c

Hence, TranEd will compute the Intergreen from Link 16 to11 to have a value n/c. In TRANSYT, this is the correct scenario because Link 16 will be green at the same time as Link 11 in stage 2 (Fig 11).

Apply the converted Link Intergreens shown below

	11	12	13	14	15	16	91	92	93
11		–	7	–	5	–	–	5	–
12	–		7	–	5	–	–	5	–
13	5	5		6	–	–	5	–	9
14	–	–	6		7	7	–	–	8
15	6	6	–	5		–	8	–	7
16	–	–	–	–	–		–	–	–
91	[illegible]	–	12	–	12	–		–	–
92	8	8	–	–	–	–	–		–
93	–	–	8	8	8	8	–	–	

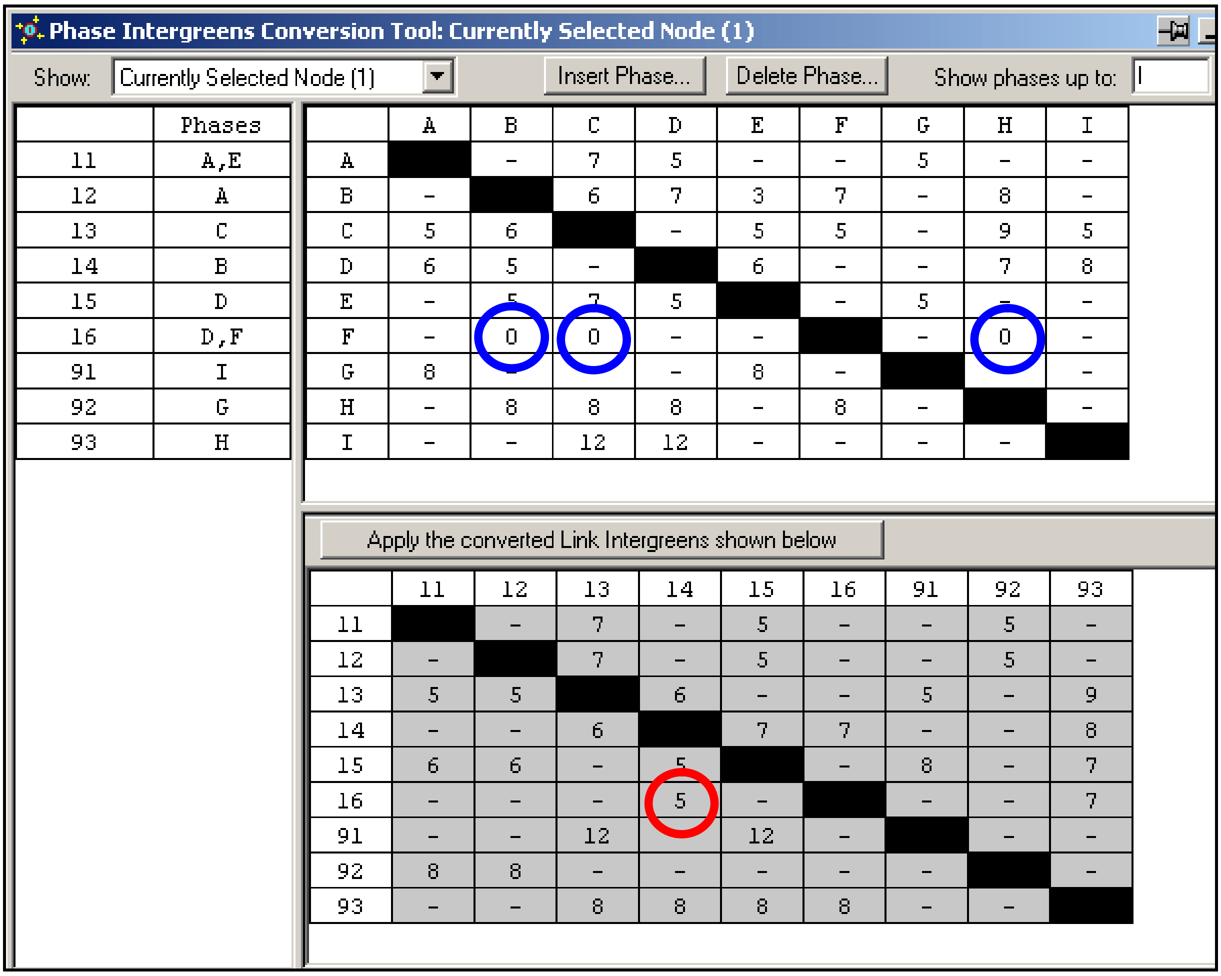
Fig 16 – Link Intergreen from 16 to 11 (not yet converted)

Conversion 5 – Link 16 to 14

Link 16 is controlled by phases D and F, Link 14 by phase B. phases B and D are full traffic phases, F is a left Filter. The Intergreens which affect these links are as follows:-

phase D to B Intergreen which is 5 seconds
phase F to B Intergreen which is n/c

According to conversion rules, the converter will calculate the Intergreen from Link 16 to 14 to be n/c. Clearly, this is incorrect because the Intergreen should be 5 seconds since Link 16 can never run with Link 14. The error has occurred because in the original Intergreen matrix, there were no Intergreens away from the Filter. This is because in LINSIG and indeed when configuring TR2210A forms, the rules regarding filter terminations mean that the filter is normally terminated with the full green or in some cases continues to run with the full green. However, TranEd/TRANSYT cannot check for this scenario because phases are not part of the data structure and are unable to check for this. Hence, for the Converter Tool to work correctly, the user must specify conflicts away from the Filter phase. This is the reason why the Converter Tool will not allow the Intergreens to be converted. To resolve the problem, look for green coloured squares in the phase Intergreen table which indicates cells which have no matching pair (not symmetrical) and therefore should be the ones to check first. The absolute value of the Intergreen is not strictly critical since the Converter Tool will take the highest Intergreen to the filter or full green anyway. Since, in practice, these two Intergreen values should be the same, an entered value of zero or one will suffice.



	Phases
11	A,E
12	A
13	C
14	B
15	D
16	D,F
91	I
92	G
93	H

	A	B	C	D	E	F	G	H	I
A		-	7	5	-	-	5	-	-
B	-		6	7	3	7	-	8	-
C	5	6		-	5	5	-	9	5
D	6	5	-		6	-	-	7	8
E	-	5	7	5		-	5	-	-
F	-	0	0	-	-		-	0	-
G	8	-	[illegible]	-	8	-		[illegible]	-
H	-	8	8	8	-	8	-		-
I	-	-	12	12	-	-	-	-	

	11	12	13	14	15	16	91	92	93
11		-	7	-	5	-	-	5	-
12	-		7	-	5	-	-	5	-
13	5	5		6	-	-	5	-	9
14	-	-	6		7	7	-	-	8
15	6	6	-	5		-	8	-	7
16	-	-	-	5	-		-	-	7
91	-	-	12	[illegible]	12	-		-	-
92	8	8	-	-	-	-	-		-
93	-	-	8	8	8	8	-	-	

Fig 17– Calculated Link Intergreens (ready for conversion)

To summarise, the Converter Tool will not transfer Intergreens into TranEd unless the phase matrix is completely symmetrical (i.e. no green coloured cells). This ensures that the user checks for missing conflicts before making the transfer. Providing the conditions for the conversion are met, the button ‘Apply the converted Link Intergreens shown below’ will be activated (Fig 17). Clicking the button will transfer the Intergreens (Fig 17) into the Link Intergreen View (Fig 18).

Link Intergreens View: Currently Selected Node (1)

Show: Currently Selected Node (1)

	11	12	13	14	15	16	91	92	93
11		-	7	-	5	-	-	5	-
12	-		7	-	5	-	-	5	-
13	5	5		6	-	-	5	-	9
14	-	-	6		7	7	-	-	8
15	6	6	-	5		-	8	-	7
16	-	-	-	5	-		-	-	7
91	-	-	12	-	12	-		-	-
92	8	8	-	-	-	-	-		-
93	-	-	8	8	8	8	-	-	

Fig 18 – Link Intergreen matrix (after conversion)

Conflict Errors preventing Transfer

Generally speaking, if you use TranEd to construct a network in a particular order (e.g. phase Intergreens, link Intergreens then stage construction), then a problem will not arise. However, under different circumstances, particularly if Intergreens are being added to a TranEd file for checking purposes, then the Converter Tool will not permit the transfer of an Intergreen if it would cause a conflict.

For example, consider the following stages (Fig 19) set up in error (an easy mistake in TRANSYT since conflicts are determined indirectly). Note that the left filter (link 16) is in conflict with the pedestrians (link 93) in stage 2.

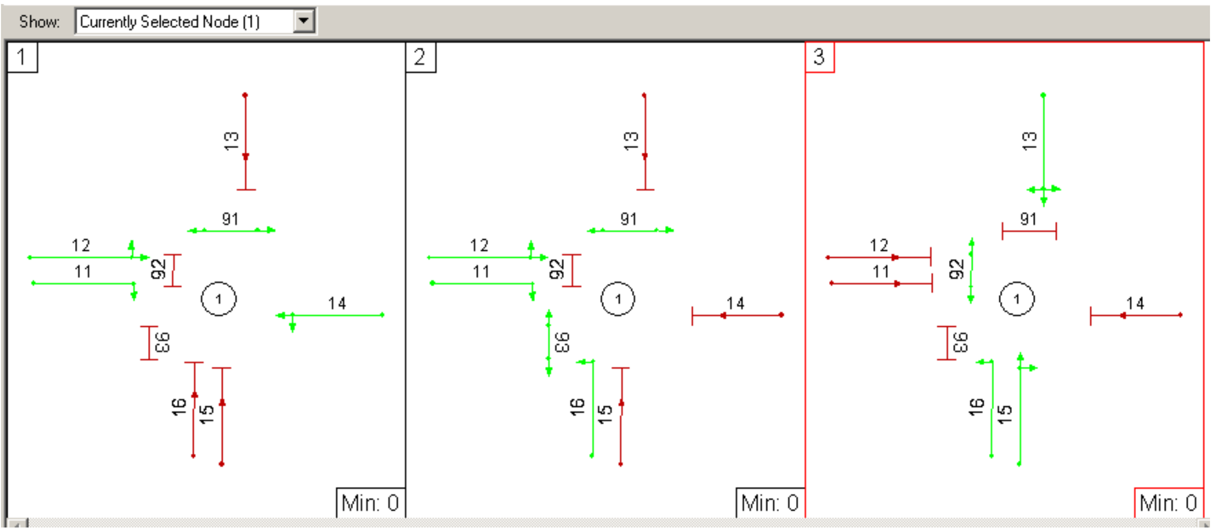
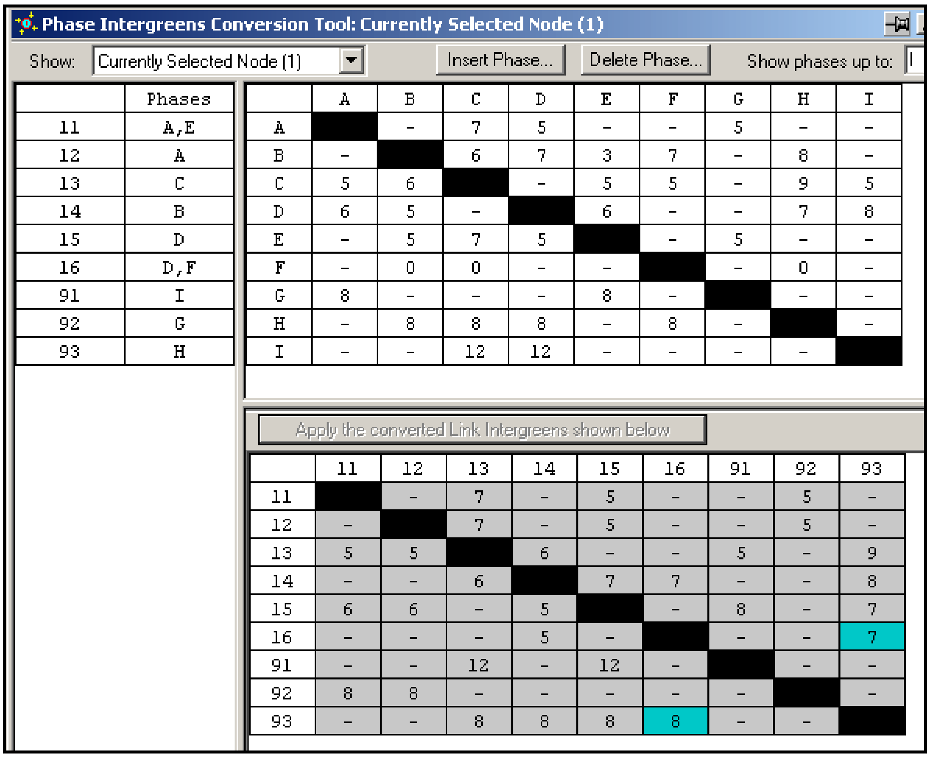


Fig 19 – Stages Generated in Error without Link Intergreens



	Phases
11	A,E
12	A
13	C
14	B
15	D
16	D,F
91	I
92	G
93	H

	A	B	C	D	E	F	G	H	I
A		-	7	5	-	-	5	-	-
B	-		6	7	3	7	-	8	-
C	5	6		-	5	5	-	9	5
D	6	5	-		6	-	-	7	8
E	-	5	7	5		-	5	-	-
F	-	0	0	-	-		-	0	-
G	8	-	-	-	8	-		-	-
H	-	8	8	8	-	8	-		-
I	-	-	12	12	-	-	-	-	

	11	12	13	14	15	16	91	92	93
11		-	7	-	5	-	-	5	-
12	-		7	-	5	-	-	5	-
13	5	5		6	-	-	5	-	9
14	-	-	6		7	7	-	-	8
15	6	6	-	5		-	8	-	7
16	-	-	-	5	-		-	-	7
91	-	-	12	-	12	-		-	-
92	8	8	-	-	-	-	-		-
93	-	-	8	8	8	8	-	-	

Fig 20 – Converter Tool showing why Transfer is prohibited

If the phase Intergreens are now added to the Converter Tool, the table of link Intergreens in the lower half of the Tool show two blue coloured cells. This indicates that the conversion cannot be carried out because there is a conflict between link 16 and 93 which is not compatible with the stage View. To correct the error, either link 16 or link 93 must be made inactive in stage 2.

Summary

To many avid TRANSYT users, the process which is described above may seem extreme and over complicated. The question is very simple. How have TRANSYT users being carrying out this process over the last 30 years. Have Intergreens been converted carefully into link lag times and have conflicts been checked thoroughly. From the relatively small sample of TRANSYT models I have seen, this does not seem to have been the norm. If the effect of Intergreens is not modelled correctly in TRANSYT, then the accumulation of errors resulting from each stage change can be dramatic, putting a serious doubt against the creditability of the TRANSYT model. Furthermore, it would be interesting to know what methods have been used to check TRANSYT models and indeed how often does anyone ask for the phase Intergreen calculations prior to checking. Irrespective of what methods have been adopted in the past, the new version of TranEd coupled with the phase Converter Tool will allow signalled junctions in TRANSYT to be modelled with a greater degree of precision whilst at the same time reducing the likelihood of errors and staff costs. It will also provide a far more robust way of checking that Intergreens / conflicts are being correctly modelled.

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