

Lincolnshire County Council

A17 Cross Keys Swing Bridge

SCADA/PLC and Plant Upgrade Feasibility Study

DGE Job No. 431802

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Document Status

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2.0	30/11/21	CW	Revised in line with LCC comments; Plant options added.
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Scope

The first part of this report is a feasibility study that assesses the A17 Cross Keys Swing Bridge's **SCADA and PLC** systems. It covers the following options:

A. Appraise the existing system and do no enhancements i.e. do nothing other than maintain status quo. What is the residual life expectancy of the system? How maintainable, availability of parts? Are there any faults within the current programming causing the Bridge to cut out during operation?

B. Enhance the existing system. What alterations can be made to the existing system to give reliability and resilience? What is the gain in resilience and design life?

C. Major Overhaul of the existing system. What can be done to give long term resilience and reliability? Reference to the Series 7000 of the specification for Highway works with regards design life, etc. should be made.

The second part of this report considers two options for the replacement of the bridge's **plant and machinery**:

A. Renew plant and machinery in situ (as far as possible).

B. Replace all plant and machinery, moving as much as possible to the shore.

Planning Considerations: The Bridge is Grade II* listed structure, therefore any implications of the listed status from the feasibility options is to be considered (will any changes to the operating systems require listed building consent)

Operational Background

The A17 Cross Keys Swing Bridge is a critical national infrastructure asset. Its operation affects a primary road route and a navigable river. The Bridge is included within LCC's business continuity plan and is seen as a major risk to the region should it fail, in particular disruption to shipping and the Port of Wisbech. Similarly the A17 is the only route from Lincolnshire to Norfolk and is the main corridor for the agri-food industry. Should the Bridge fail and block either route or even worse both routes (failing during a swing, making neither river nor road available) the economic impact on the region is potentially devastating, damaging the reputation of the County Council.

The Bridge is also governed by an Act of Parliament – The Lynn and Sutton Bridge Railway Act 1861, where it is unlawful for the Bridge to delay or detain shipping on the River Nene. Therefore LCC could be subjected to civil proceedings (if not criminal) if a neglect of duty is identified and proved.

Part 1 – PLC/SCADA

System History

The Bridge underwent a major M&E overhaul around 1986 which included its first PLC-based control system. That original PLC was replaced with the current Allen-Bradley PLC and SCADA setup around 2001.

The primary SCADA PC in the Turret was replaced in 2014. The backup SCADA PC in the Plant Room is the original.

System Function

The automation system comprises the PLC and two SCADA PCs – one in the Turret and one in the Plant Room – to provide a degree of redundancy. The PLC controls the hardware on the Bridge i.e. pumps, jacks etc. in response to user control inputs from either of the SCADA PCs, and plant status inputs from the field.

The system is set up to operate semi-automatically – the operator is required to sequentially initiate each stage of the process. This ensures operators remain aware of the Bridge's and plant's status in the event of problems. The PLC is programmed in ladder logic.

In the event that both SCADA PCs and/or the PLC fail, a manual override function is provided. This allows an operator to directly control the plant but carries some risk as it bypasses all of the status and safety interlocks provided for the PLC. The interfaces are a panel in the Turret and the portable panel – the 'biscuit tin' – in the Plant Room. Given the absence of feedback, the manual override really requires an extra operator on site to assist with process checks.

System Lifespan

The automation industry broadly agrees on the following lifespans for components:

PLC modules:	15-25 years
Power supplies:	10-15 years
PCs (SCADA or programming tools):	5-15 years

The Bridge's PLC has been in continuous operation for 20 years. In that time, there have been no significant issues with the PLC hardware and only minor modifications to the PLC software.

The Turret SCADA PC failed after approximately 13 years and had to be replaced. The Plant Room SCADA PC has remained in continuous operation for 20 years.

The loss of one SCADA PC is mitigated by the presence of the other but they remain the most vulnerable elements of the system. Anything beyond a straightforward power supply failure that does not damage the board or drive will be fatal. Their software is unrecoverable and untransferable.

The most limiting aspect is engineer connectivity for maintenance, diagnostic and repair activities. The installed hardware has outlived its programming tools – legacy software is incompatible with modern operating systems and legacy interfaces (e.g. serial ports, PCMCIA cards) are increasingly incompatible with modern PCs and laptops.

It is not possible to predict when or what the next failure will be; only that the inevitable is getting nearer.

System Failure Mitigation – Manual Overrides

Failure of the PLC/SCADA system is mitigated by the provision of the manual overrides – the portable panel in the Plant Room and the fixed panel in the Turret. Although powered from the PLC cubicle, these interfaces bypass the PLC system and drive the control outputs directly. However, safe manual operation of the Bridge requires training, experience and additional personnel as the override bypasses all of the PLC's process and status interlocks, e.g. limit switches. The fact that the manual override is invariably needed in an already-stressful situation (i.e. PLC/SCADA fails as a ship is approaching) tends to exacerbate those risks.

Manual control of the Bridge is 'by eye' but is also 'blind'. It should not be relied upon as a satisfactory long-term alternative to PLC/SCADA control.

System Recoverability

In the event of PLC/SCADA failure, the risks associated with manual override are increased due to the time and effort that will be necessary to restore – if not replace – the system because:

- A failed SCADA PC cannot be restored. The SCADA system is obsolete, unsupported and incapable of running on modern PC operating systems. The SCADA PCs are running Windows 7 which went out of support in January 2020.
- The PLC hardware (Allen-Bradley SLC500 range) has been discontinued. No spares are held on site. At present, all PLC hardware is obtainable from third-party suppliers either new or second-hand with limited warranty and support, or none. Availability of key components can only diminish from this point forward and costs can be expected to rise.
- The old 'engineer's laptop' has software that is capable of backing-up and reloading the existing PLC programme. It does not have software capable of amending the programme. The code is considered over-complicated with multiple tie-ins that serve no purpose. These have been suspected as causes of otherwise unexplained operating faults.

In summary, a PLC hardware failure **may** be repairable within a reasonable period at reasonable cost. The eventual failure of both SCADA PCs will leave the PLC system inoperable.

Risk Analysis

To recap: the manual override facility means there is no inherent operational risk from PLC and/or SCADA failure – assuming that the manual override is used correctly and in time.

Operational impact is thus a consequence of incorrect (or non-) operation of the manual override. This is identical across the various options. It does not matter whether the system is the old one or a new one: if it fails, the manual override is necessary and the following risks arise:

Risks of incorrect operation of Bridge in manual override mode		
Risk	**Consequences**	**Impact**
Bridge will not swing to open river	Structural damage to Bridge and/or shipping Inconvenience and loss of revenue to Port of Wisbech, shipping companies and their customers. Civil/criminal proceedings/fines against LCC	**4**
Bridge will not swing back to open road	Significant traffic congestion on diversion route via Wisbech. Inconvenience and loss of revenue to road users. Civil/criminal proceedings/fines against LCC	**4**
Bridge fails during swing so as to close road and river	Structural damage to Bridge and/or shipping Inconvenience and loss of revenue to Port of Wisbech, shipping companies and their customers. Significant traffic congestion on diversion route via Wisbech. Inconvenience and loss of revenue to road users. Civil/criminal proceedings/fines against LCC	**5**

What changes across the options is:

- The likelihood of a PLC/SCADA failure occurring that requires manual override operation. Intuitively, an old system is more likely to fail sooner rather than later.
- The remediation period. While the PLC/SCADA system is being repaired or replaced, the Bridge must be run in 'manual override'. The longer this period, the greater the likelihood of the Bridge being put out of service due to operator error.

Consequently, the objective of this feasibility study is to identify an economically-viable solution that provides:

- A safe and efficient means of operating the Bridge under PLC/SCADA control.
- A resilient system that is unlikely to fail within the medium term (circa 25 years).
- A supported, maintainable system that can be implemented and repaired, should it fail, with minimum downtime and reliance on manual override operation.
- Safer operation in manual override in the event PLC/SCADA failure or maintenance.

Options

Option A - Do Nothing

In the event of PLC failure or the failure of both SCADA PCs, the Bridge can be operated via the manual overrides. This introduces process risk – the overrides bypass limit and safety interlocks – and cost/resource issues if a second or third man is deemed necessary.

Repair of the existing SCADA PCs is not possible – both the SCADA software and the operating system are out of support. If one SCADA PC fails, the Bridge can be operated via the remaining one for as long as that lasts.

Physical repair of the PLC hardware may be protracted and expensive – or simply impossible – depending on the availability of now-discontinued equipment. When spares are no longer procurable, the system will be unmaintainable. The facility to re-upload a backup of the PLC programme still exists by means of the legacy engineer's laptop but this too may fail irreparably.

If the PLC/SCADA system is to be 'run into the ground' to extract maximum value, we would recommend the following actions are taken to prolong the life of the system, plant and structure:

- Ensure operators are trained and practised in operating the Bridge via the manual overrides in the event of PLC/SCADA failure.
- Periodically clean the SCADA PCs – particularly their PSUs – using compressed air.

In our opinion, the existing, unsupported and irreplaceable SCADA PCs are considered the weakest link in the system and we would reasonably expect at least one of them to remain functional for another 5 years (at which time the Turret PC will be 12 years old and the Plant Room PC will be 25 years old).

The PLC is operating in a much more stable environment and may be expected to remain in operation for approximately 10 years. Spares may be available to keep it going beyond this.

Option B - Enhance Existing System

In the event of PLC failure or the failure of both SCADA PCs, the Bridge can be operated via the manual overrides. This introduces process risk – the overrides bypass limit and safety interlocks – and cost/resource issues if a second or third man is deemed necessary.

If the PLC/SCADA system is to be maintained to extract its maximum value, we would recommend the following enhancements to prolong the life of the system, plant and structure in descending order of priority/utility:

- Procure 2 off new SCADA PCs. This should include supported SCADA software capable of being easily transferred to a new PC in the event of failures.
- Procure PLC spares (they are still available at the time of writing).
- Overhaul the manual overrides.
- Slave PLC position/status inputs to an indicator/mimic panel to assist direct manual operation. This additional task may be justifiable due to the increased reliance on the manual overrides.
- Rationalise and simplify the process and PLC code to minimise risk of glitches.

It must also be borne in mind that the manual overrides are also 20 years old. We would recommend that these are overhauled – if not replaced – as they are the critical backup to the PLC/SCADA system. The portable 'biscuit tin' is particularly prone to wear and tear through handling.

Option C - Major Overhaul of Existing System

The PLC itself has proved reliable and the pair of SCADA PCs, despite being the weak links, provide a measure of redundancy. The existing PLC/SCADA system can be expected to continue for approximately 5 years but – of course – this cannot be guaranteed.

It would be prudent to proactively design, procure, configure, test, install and commission a replacement system sooner, rather than reactively later. Bipartite process review meetings would be necessary to develop a clear user requirements specification to feed into the new system's functional design process.

Like-for-like replacement of the PLC and SCADA interfaces in the Turret and Plant Room offers the following advantages:

- New supportable hardware ('rail rated' as far as possible to maximise resilience and confidence; availability of spares, awareness of component lifecycles)
- New supportable software (operating systems, programming and interface tools; subscription-based licences to guarantee support and updates; easily transferable to new hardware e.g. SCADA HMIs and engineers' laptops)
- Simplified process code (maximising reliability, maintainability and confidence)
- Improved user interfaces (SCADA HMIs instead of PCs; ease-of-use; clearer indication of existing status and fault conditions)

At the time of writing, the lead time of new PLC/SCADA hardware is approximately 30 weeks from the date of order, in which time the new code can be developed.

The installation time for the system will be of the order of 1-2 weeks with commissioning, operational and system checks over a further 1 day and 5 nights. During this period the Bridge would not be operational in automatic mode and rely on the manual override.

To further reduce downtime, it may prove feasible to pre-assemble the new PLC on a backplate so that it can be put into temporary operation whilst the existing system is removed, before its permanent installation in the cleared cubicle.

It must also be borne in mind that the manual overrides are also 20 years old. We would recommend that these are overhauled – if not replaced – as they are the critical backup to the PLC/SCADA system. The portable 'biscuit tin' is particularly prone to wear and tear through handling.

Manual Override Enhancement

An overhaul presents an opportunity to display the Bridge's status and fault signals independently of the PLC to improve operator awareness under manual override. This will reduce the likelihood of errors that risk taking the Bridge out of service. Instead of being connected directly to the PLC, status and fault signals could be terminated at a new independent marshalling facility where they can be split between the PLC and a new indicator/mimic panel.

We recommend further discussion and investigation of the manual overrides to identify useful and economic improvements to this critical backup system.

Options Cost/Timescale Matrix

	Activities (* optional)	Budget Cost	Indicative Timescale	Option A Do Nothing	Option B Enhance	Option C Overhaul
A	Manual override training	-	4w	✓	✓	✓
	SCADA PC periodic maintenance	-	Ongoing	✓	✓	✓
B	2x PCs with supported OS and supported backwards-compatible SCADA package	M: £10K L: £20K	20w		✓	
	Acquire PLC spares	M: £6K L: £1K	4w		✓	
	* Configure / test PLC spares	L: 1.5K	6w		✓	
	* Replace PLC components; retain old as configured / tested spares	L: 1.5K	8w		✓	
	* Rationalise/simplify PLC code	L: £30K	20w		✓	
	* Overhaul manual overrides	M: £1K L: £1K	4w		✓	
	* Plant Room indicator/mimic panel	M: £1.5K L: £7.5K	8w		✓	
C	New supportable PLC/SCADA hardware/software	M: £40K L: £50K	30w			✓
	* Overhaul manual overrides	M: £1K L: £1K	4w			✓
	* Plant Room indicator/mimic panel	M: £1.5K L: £7.5K	8w			✓
			Approximate Budget	**-**	**£35K-£80K**	**£90K-£100K**
			Anticipated Lifespan	**5 years**	**10 years**	**20 years**
			Likelihood of Failure Over Lifespan	**HIGH**	**MED-HIGH**	**LOW**

Options Risk Matrix

Risk	Consequences	Impact	Likelihood			Outcome		
			A	B	C	A	B	C
SCADA PC/HMI failure (single)	Short-term disruption at time of failure. Operate Bridge via backup SCADA PC.	1	5	1	1	5	1	1
SCADA PC/HMI failure (both)	Short-term disruption at time of failure. Operate Bridge via manual override. Additional personnel may be required as observers. Increased risk of errors leading damage to Bridge and/or road/river closure over long remediation period.	3	4	1	1	12	3	3
PLC failure	Short-term disruption at time of failure. Operate Bridge via manual override. Additional personnel may be required as observers. Increased risk of errors leading damage to Bridge and/or road/river closure during the remediation period.	3	4	3	1	12	9	3

Recommendation

Option C: the complete replacement of the PLC/SCADA system is Dodd Group's recommendation.

The cost of providing a properly-engineered, maintainable and future-proofed system is not significantly higher than attempting to 'enhance' the existing system (Option B) for the remainder of its indefinite lifespan. Option C's financial commitment is a positive investment to move forwards; Option B is a gamble to stand still.

This option will incorporate a formal review of the process and plant interfaces by all stakeholders to agree the user requirement specification needed to initiate and control the automation code design phase.

Dodd Group further recommends that **the manual override systems be overhauled and enhanced with an indicator/mimic panel**.

No planning implications are anticipated as no substantive changes are to be made to the Bridge's method of operation or structure. The only visible changes will be internal: new SCADA HMIs in lieu of the existing PCs.

Options A and B both accept that a new system (Option C) is likely to be required at some point over the next ten years. It is considered prudent to proactively design and install the new PLC and SCADA whilst the existing system remains functional, not after it has failed. As a reactive measure, implementation will be subject to unhelpful operational pressure and Bridge operators will be reliant on the riskier manual override during the six month delivery period.

A stock of PLC/SCADA spares is not considered necessary whilst the components are still available from the manufacturer. As the time they are flagged for end of lifecycle, a decision can be made as to whether a stock of spares should be procured to extend the maintainable life of the system.

Recommended System

The use of an industry standard Siemens SIMATIC S7-1500 PLC system is recommended. A pair of TP1500 outdoor-rated HMIs are proposed as the SCADA interfaces as these are more resilient than a PC-based option.

No change is proposed to the general concept of operation. Operators should still have to initiate each individual stage of the process to ensure they know where they are in the event of problems.

Non-Recommendations

Option A cannot be recommended. Doing nothing, running the existing system into the ground means having to implement Option C reactively at some point in the not-too-distant future. This may be considered counter-productive compared to a planned approach.

Option B cannot be recommended. Updating the SCADA and setting by PLC spares is a palliative measure that does not guarantee to keep the system in operation for another generation. This is exacerbated by a reliance on legacy PLC software tools that may not remain functional over that period. As and when the system does fail, Option C will again have to be implemented reactively as above.

The worst case – in financial terms – is Option C's spend being necessary sooner rather than later if Option B fails to usefully extend the life of the system.

Compromise Option A/C

The bulk of the new system's 30-week delivery period is down to the automation code's specification and design. Assuming the code can be future-proofed and appropriate hardware is available 'off the shelf', a compromise option might be:

- Design, develop, test and 'seal' new automation code (as per Option C)
- Specify – but do not procure – suitable hardware
- Implement Option A
- At the point of failure, procure and install current equivalent hardware and load 'sealed' code

The delivery period of the new system could be significantly shortened to the time taken to implement the hardware change though it would still be a reactive – not a planned – exercise. It does allow maximum use to be made of the existing system before replacement. There may also be some advantage in spreading the costs over the two separate periods of activity.

Dodd Group cannot wholeheartedly recommend this approach. Although procedurally feasible, there is a risk to developing automation code that is not going to be put to use: the absence of real world testing may result in code that is not fit for purpose when it is eventually needed, without any ownership of the issue.

Other Works

The provision of enhanced or new systems are likely to result in the Bridge being taken out of service for a period. Consideration should be given to the concurrent execution of other works requiring downtime, e.g. the provision of new, maintainable hydraulic pumps.

Part 2 – Plant and Machinery

System History

The Bridge underwent a major M&E overhaul around 1986. The original plant and machinery is becoming increasingly difficult to maintain due to its age and availability of consumables and spares, both for plant and control gear. Recent fault investigations suggest that there are inconsistencies in pump wiring.

Operational Risk Analysis

Risks of incorrect operation of Bridge due to plant failure		
Risk	**Consequences**	**Impact**
Bridge will not swing to open river	Structural damage to Bridge and/or shipping Inconvenience and loss of revenue to Port of Wisbech, shipping companies and their customers. Civil/criminal proceedings/fines against LCC	**4**
Bridge will not swing back to open road	Significant traffic congestion on diversion route via Wisbech. Inconvenience and loss of revenue to road users. Civil/criminal proceedings/fines against LCC	**4**
Bridge fails during swing so as to close road and river	Structural damage to Bridge and/or shipping Inconvenience and loss of revenue to Port of Wisbech, shipping companies and their customers. Significant traffic congestion on diversion route via Wisbech. Inconvenience and loss of revenue to road users. Civil/criminal proceedings/fines against LCC	**5**

Overview

The condition and maintainability of the existing plant is such that the replacement of individual elements of the system is not practicable.

Like-for-like replacement of the whole system (i.e. a pair of new 30kW pumps, a refurbished MCC and a replacement generator) has been excluded as an option due to the unsatisfactory performance of the Bridge when running on a single pump under a pump failure condition.

We propose that the new plant and machinery will comprise of a pair of 55kW hydraulic pumps operating in a duty/standby configuration. Each pump will be capable of driving the bridge at an acceptable speed in isolation, thus providing a full-performance backup. The existing MCC and generator are not capable of accommodating the new pumps so both will need to be replaced.

The site's existing mains supply is adequate to run a single pump so a potentially-significant DNO supply upgrade is not necessary and has not been considered.

Options

A – Renew plant and machinery in situ: Because of the increase in pump size, new softstarts and a new MCC will be required. However, we propose to retain the existing MCC as it is the point of termination for the existing sensor cables. To create space within the Plant Room for the new MCC, we propose to remove the generator which will be replaced by a new, suitably-rated package generator onshore (subject to planning approval). The existing hydraulic oil tank will be retained as it has sufficient capacity for the proposed operating regime.

B – Establish an all-new Plant Room onshore: This proposal requires the provision of a new onshore enclosure to accommodate the two new hydraulic pumps, MCC with softstarts, generator, fuel and hydraulic tanks. It is anticipated that the enclosure will need to be of a significant size, and of a style sympathetic to the heritage value of the site.

Recommendation

Although an onshore Plant Room offers advantages in access and maintainability, **Option B** introduces a number of significant issues:

1. Planning requirements could be onerous and time consuming because of the new onshore Plant Room plus the need for additional pipe/cable bridges between the shore and the structure.
2. All power, signal and comms cables, and all hydraulic lines must transit from shore to structure and be flexible enough to permit the rotation of the turntable.
3. Hydraulic lines may need trace heating and/or lagging, plus some form of anti-spill containment where they run over or alongside the river.
4. A large number of flexible lines and cables has the potential to become a maintenance millstone and exacerbate operational risk.
5. Though the hydraulic oil tank could be properly-bunded onshore, the increased length and movement of the lines increases the risk of leaks over water.

We recommend **Option A** is implemented for the following reasons:

1. The change in visual amenity is limited to the new generator enclosure.
2. Flexible connections through the turntable are limited to mains power only.
3. The hydraulic systems are static and completely enclosed within the structure, minimising wear and the risk of consequent leaks. It also permits retention of the existing hydraulic tank.
4. The onshore generator reduces environmental risk in that it obviates the requirement for diesel fuel to be transported and stored over the watercourse.

The integrity of the Plant Room and associated structures is assumed to be satisfactory.

Design and planning costs are EXCLUDED from the above table as these are to be borne by LCC.

Operational Risk Analysis

The risk analysis is the same for both options as they are functionally identical. The comparison is between Options A or B and 'do nothing' - 0

Risk	Consequences	Impact	Likelihood		Outcome	
			A/B	0	A/B	0
Mains failure / changeover to generator	Short-term disruption at time of failure. Slow swing due to limitation of single pump operation. Reduced reaction time due to above factors.	3	1	1	3	3
Generator failure	Bridge cannot swing – disruption to road, river, or both.	5	1	3	5	15
One pump/ drive fails	Slow swing - reduced reaction time (not applicable to new pumps).	0 / 3	1	3	0	9
Both pumps/ drives fail	Bridge cannot swing – disruption to road, river, or both.	5	1	2	5	10

Options Cost Matrix (including recommended PLC overhaul)

Activities	Option A On Bridge	Option B Onshore
Replacement Pumps	£100K-£120K	£100K-£120K
MCC	£80K-£100K	£80K-£100K
Generator (onshore)	£80K-£120K	
Relocation of Hydraulics	-	£300K-£400K
Relocation of Electrical	-	£400K-£500K
Scaffolding	-	£120K-£150K
Safety boat	-	£30K-£35K
Building	-	£50K-£80K
Civils / groundworks	-	£30K-£50K
Structural pipe/cable bridge	-	£30K-£60K
PLC Overhaul (Option C)	£100K	
Total	**£360K-£440K**	**£1.32M-£1.72M**