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Finding the Right Bus? Costing Analysis for Selecting Fieldbus Technologies

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Abstract: In the spring of 2001 a major food company began considering the use of new fieldbus technologies to reduce costs and improve system reliability. Since these technologies were a significant departure from their standard control strategy, an economic model was developed to determine the best possible combination of these buses. This model is believed to be unique in that it considers a variety of buses simultaneously. It addition, the model factors in cost items such as the I/O mix in the plant, the wiring layouts and engineering costs in addition to usual materials requirements.

The results of this study[a] showed that that using fieldbuses result in significant savings in project costs, probably in the range of 30%. It also determined that the ideal implementation typically involves two or more different buses in facility, rather than a single bus. The results of the model were then correlated with user interviews and literature searches to compare the cost, maintenance and engineering issues of the various fieldbus solutions.

This presentation will discuss the application of this model and how it can be used to select the 'right' bus for a project. It will also compare the cost, maintenance and engineering advantages fieldbus solutions vs. traditional solutions.

Keywords: Fieldbus, Devicebus, Economics, Project Estimation, Modelling

1. Background

A key component of any project is funding approval. In order to get that approval there are a number of items that must be addressed, especially for a project introducing new technology such as fieldbuses. According to Jim Montague of Control Engineering magazine, these items include[b]:

- Determine the specific needs of the application
- *Estimate the specific material, labour and other cost savings*
- Demonstrate the ease of installation, configuration and maintenance
- Quantify possible improved quantity, quality and accessibility
- Calculate better capability, capacity and throughput
- *Show possible risks and how they have been mitigated*
- *Estimate reduced downtime and faster time-to-market*
- Determine project expandability and its contribution to modularity of the unit operation, and
- Relate the project to the organization's overall capital expenditures and core business goals.

It is clear from this list that most initial project questions have a strong economic component. For the design engineer, this requires an unbiased method to compare and, if necessary, combine technologies to find the most economic control system solution. Since there are so many different bus technologies available it is difficult to know which ones to choose for a project.

In the spring of 2001 a major food company faced this exact problem as they began considering the use of new fieldbus technologies to reduce costs and improve system reliability. Since these technologies were a significant departure from their standard control strategy, an economic model was developed to compare the materials, installation and engineering costs of the various fieldbus solutions. In conjunction, a combination of user interviews and literature searches was undertaken to compare the cost, maintenance and engineering issues of the various fieldbus solutions and provide correlation for the model.

This paper describes the model used to help the decision process by comparing installed costs for four bus technologies versus a traditional control system, thus helping answer a number of the questions highlighted in the above list.

2. The Buses

To begin, let's identify the buses being compared along with their target application strengths. According to Intech Magazine[c], there are over 27 different bus technologies currently proposed as a possible industrial field or device bus. Since this is an unwieldy number to properly analyse in depth, the list of buses considered in the model was reduced to four, based on current market share and the bus being a true "fieldbus"; in other words, a digital, two-way, communications link for intelligent field devices. Based on these criteria, the buses analysed in the model were AS-i, DeviceNet, Profibus-DP and Foundation Fieldbus H1.

2.1 AS-i

AS-Interface is the simplest and least expensive of all the buses. It intended to allow discrete devices as small as push buttons or photocells to be connected on a bus. The data payload is only 4 bits, so it cannot be used for analogue control without some added complexity, but is very effective for simple devices. Typically, AS-i is targeted at the discrete manufacturing industries or other applications with a high discrete I/O count.

The physical layer technology is based on a special flat cable or standard shielded twisted pair cable. Both allow field devices to be powered over the bus. The topology is trunk and drop and distances are strictly limited to 100 meters. AS-i uses a memory location mapping scheme and has no true device descriptor system. It is a single master bus and does not provide redundancy. Its major strength is its absolute simplicity.

2.2 DeviceNet

DeviceNet is based on the CAN (Controller Area Network) protocol and is targeted to the manufacturing industries with the majority of its products used for multiple discrete I/O and array output or digital output signal devices such as motor starters, variable speed drives and other on/off devices.

The physical layer technology is based on a special five-conductor cable that allows field devices to be powered over the bus. The topology is “trunk and drop” and distances are strictly limited to either a 100-meter or 500-meter trunk, depending on the cable used. A DeviceNet segment can have a maximum of 64 devices.

DeviceNet’s media access control is CSMA/CA, but it effectively runs in master-slave mode most of the time. This provides the bus with good time synchronization, but with no possibility for redundancy.

The devices are defined to the host systems through the use of an Electronic Data Sheet (EDS), a standardised ASCII file that provides a description of the device including a definition of the data available for transmission.

2.3 Profibus-DP

The Profibus family currently contains three different buses; Profibus-DP (Device Peripheral), Profibus-PA (Process Automation) and ProfiNet. For this model the authors focused on Profibus-DP, due to its dominant market share as compared to the other two styles.

Profibus-DP is a discrete device bus using a master-slave architecture. At the physical layer Profibus-DP uses EIA-485 and asynchronous technology. The data rates run from 9600 bps to 12 Mbps, but the high speeds come at the expense of very short run lengths (100 meters) and a fairly restrictive daisy-chain topology. As a result, Profibus-DP is rarely run at data rates above 500 Kbps. Field devices cannot be powered over the bus and the bus must be shut down to add new devices.

Profibus-DP uses a memory location-mapping scheme as compared to a tag-based system like DeviceNet or Foundation Fieldbus. Vendor prepared device database (GSD / GSE) files provide device characteristic information to the system. The GSD file is the device data sheet file, while the GSE file is the device database file. Profibus DP targets similar industries and devices as DeviceNet, predominantly motor starters and other discrete signal devices.

2.4 Foundation Fieldbus

Foundation Fieldbus comes in 2 flavours, H1 and HSE (High Speed Ethernet), though at present there are a limited number of HSE devices or applications. As a result the model focuses on the H1 protocol.

The H1 protocol operates at 31.25k, loop powered and supports segments up to 1900 meters total length. A vendor prepared Device Description (DD) file describes the functionality of a Fieldbus device. The DD file also requires an associated CFF (Common File Format) ASCII text file a host system can use to configure the system off-line. Until recently, Fieldbus[1] has had limited support for discrete applications though a number of larger discrete valves and field mounted discrete I/O stations are now available. Fieldbus also supports redundancy of both protocols and uses cyclic communications to publish and subscribe to data on the network.

Devices can be added and removed from the network, while it is live, since the devices are ‘recognized’ by the host when they are plugged in or removed. Fieldbus is the only fieldbus protocol that supports control in the field.

Fieldbus is designed for use in the continuous process industries, with its strength in analogue control of single and multivariable field elements.

3. The Model

An economic model was developed to compare the four buses along with traditional “hardwired” installation costs. This model differs from most because it allows the user to assign a mixture of devices to different fieldbuses. For example, from a list of devices, it is possible to assign the analogue transmitters to Foundation Fieldbus, the drives to Profibus-DP and the discrete valves to AS-i. The authors believe this represents a more realistic representation of the typical fieldbus installation today, since few plants have only one bus installed.

The data flow in the model is shown in Figure1. At the core of the model are 3 different types of spreadsheets for data inputs and calculations:

Constants — costs and rates associated with equipment and labour.

Bus Details — the main calculation area and detailed summary of the costs associated with each bus type.

Inputs & Results Summary — table to compare various combinations of bus installations and then see the impact of those changes on the total installed cost.

3.1 “Constants” Spreadsheet

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[1] **The term Fieldbus with a capital ‘F’ indicates Foundation Fieldbus, while fieldbus with a lower case ‘f’ is used to mean the generic term for industrial digital communications networks.**

The most important worksheet in the model is the one containing the constants as it

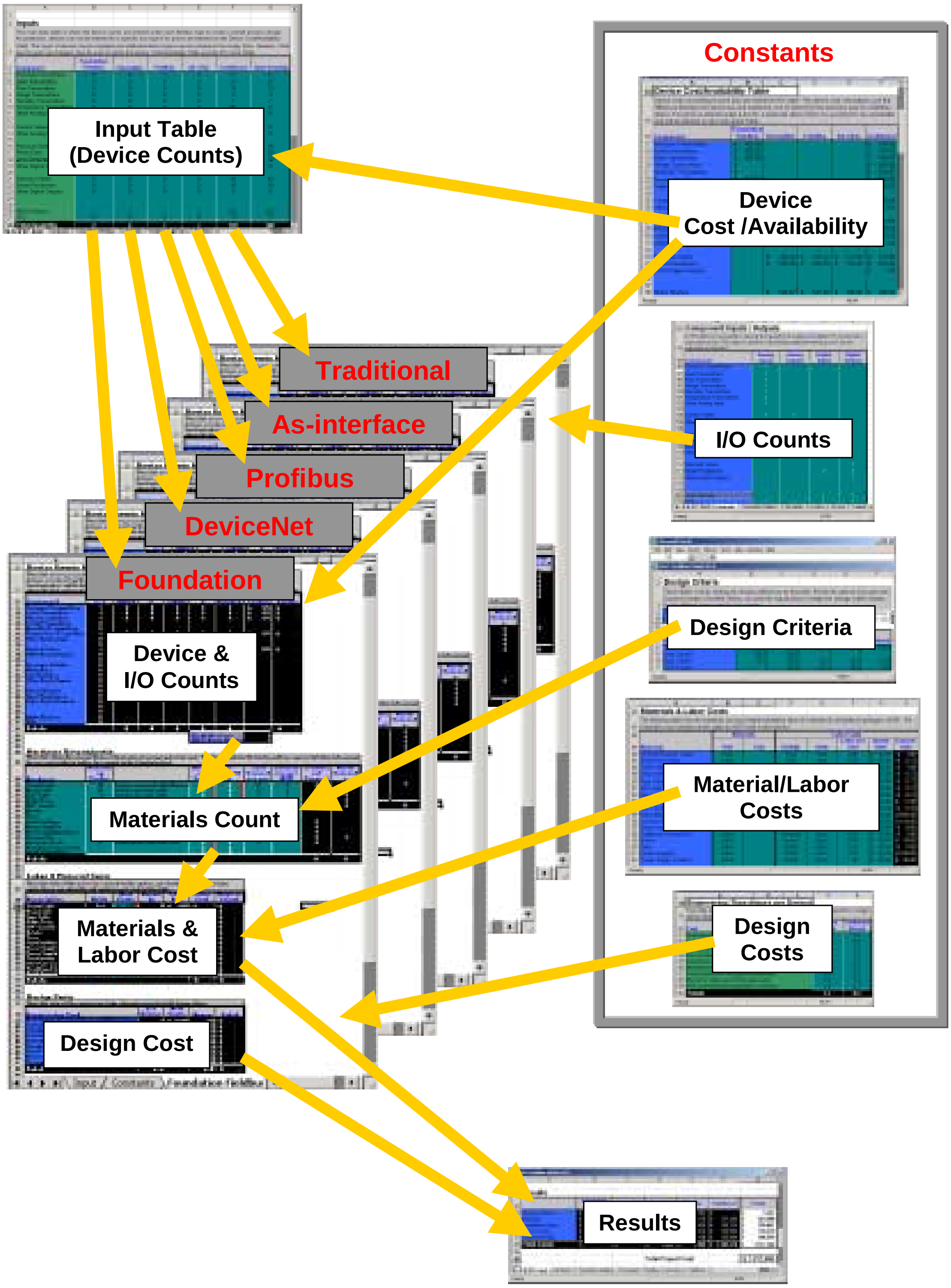

Figure 1: Internal Data Flow of the Fieldbus Economic Model

forms the basis for all subsequent calculations. The worksheet itself is divided into five tables:

Design Criteria — where plant design preferences such as connectors, conduit versus tray, and average cable trunk or drop lengths are specified.

Device Cost/Availability— Device costs according to each bus are entered in this table. This information is then used calculate the difference between the device bus and traditional cost and determine the premium paid for a fieldbus device. If no price is entered under a bus for a particular device them it is assumed to be unavailable and is blocked on the main Input sheet.

Materials & Labour Costs— captures the costs of materials such as cabling, junction boxes, power supplies, host interface and I/O cards as well as the associated labour charges to install and commission the system.

Engineering Time — a list of all the engineering tasks associated with a project and estimated time required on a per device basis.

Component I/O List — a summary of the traditional I/O required by each device type. This data is used for calculating traditional wiring requirements.

All of the values in the constants sheet are designed to be editable by the engineer running the model. Some tables, like the Design Criteria and the Device Cost/Availability tables, are project specific and were completed by obtaining design and price estimates from local vendors. On the other hand, the Engineering Time tables are much more difficult to estimate, so these values were compiled from a number of other economic models[d],[e] as shown in Table 1. These values indicate a savings in engineering time of 54%, inline with other published estimates[f],[g].

Table 1: Comparative Costs for Engineering Hours

Task	Time per Device (hours)	
	Traditional	Fieldbus
Development of Control Strategy (P&ID Development)	2	1.0
Instrument Index development / production	0.5	0.5
I/O Address assignments	0.3	0.1
I/O List Development	1.5	0.5
Instrument loop diagram[2] design/documentation	4.0	2.0
Marshalling panel design / documentation	0.3	0.0
Field terminal box design / documentation	0.3	0.1
Electrical Cabling and termination lists	2.25	0.7
Precommissioning configuration of devices	0.5	0.5
Total	**11.65**	**5.4**

3.2 "Bus Details" Spreadsheets

The Bus Details spreadsheets are five separate sheets, one per bus type plus traditional I/O. Their purpose is to provide a main calculation area where the specific materials costs and design intricacies of each bus can be accounted for. In particular the Hardware Determination Table is where bus constraints such as the number of devices on a network or spur, the number of devices per terminal assembly, junction box or power supply, and the number of networks per host interface card are set. In general the user does not edit these values.

[2] Note: For Fieldbus systems, the loop diagram is replaced with a network diagram.

The other options on the worksheet provide the user with the ability to alter the labour and material unit costs for the particular bus system if desired. The remainder of the worksheet calculates and summarizes the design and commissioning costs of the individual systems.

3.3 "Inputs & Results Summary" Spreadsheet

The Inputs and Results Summary worksheet serves as the main user interface where actual device counts are assigned to each fieldbus system to determine the most economic overall installed cost. For example, Figure 2 shows a trial design with 387 devices, with the discrete devices, motors and drives assigned to Profibus-DP, the bulk of the analogue devices assigned to the Foundation Fieldbus, and 6 specialty analogues assigned as traditional I/O. As protection, devices cannot be entered for a specific bus type if no prices are entered on the Device Cost/Availability Table.

Component	Foundation Fieldbus	DeviceNet	Profibus	AS-i Bus	Traditional	Total Quantity
Pressure Transmitters	12	0	0	0	0	12
Level Transmitters	6	0	0	0	0	6
Flow Transmitters	13	0	0	0	0	13
Weigh Transmitters	0	0	0	0	0	0
Humidity Transmitters	0	0	0	0	4	4
Temperature Transmitters	23	0	0	0	0	0
Other Analog Input	0	0	0	0	0	0
Control Valves	13	0	0	0	0	0
Other Analog Output	0	0	0	0	2	2
Pressure Switches	0	0	13	0	0	13
Photo Eyes	0	0	20	0	0	20
Limit Switches	0	0	12	0	0	12
Other Digital Inputs	0	0	0	0	0	0
Solenoid Valves	0	0	43	0	0	43
Smart Positioners	0	0	15		0	15
Other Digital Outputs	0	0	0	0	0	0
Motor Starters	0	0	234	0	0	234
VFD	0	0	13	0	0	13
Total Quantity	**67**	**0**	**317**	**0**	**6**	**387**

Figure 2: Inputs Table with a typical device count entered

At the bottom of the worksheet is the Results Table where the comparative and total costs are shown for the combination of devices entered in the upper part of the worksheet. As illustrated in Figure 3, subtotals are also presented to show the:

Device Premium — incremental price of the fieldbus device versus a traditional analogue or digital device

Materials — cost of conduit, tray, terminals, cabinets, etc.

Installation Labour — field construction costs

Design Costs — engineering and project management costs

Commissioning — costs associated with unit start-up.

	Foundation Fieldbus	DeviceNet	Profibus	AS-i bus	Traditional	Totals
Device Premium	$ 13,664	$ -	$ 95,280	$ -	$ -	$ 108,944
Materials	$ 8,499	$ -	$ 61,528	$ -	$ 6,720	$ 76,746
Installation Labor	$ 7,368	$ -	$ 13,153	$ -	$ 4,084	$ 24,605
Design Costs	$ 27,135	$ -	$ 141,750	$ -	$ 4,793	$ 173,678
Commissioning	$ 1,958	$ -	$ 8,288	$ -	$ 691	$ 10,936
Total Costs	**$ 58,623**	**$ -**	**$ 319,998**	**$ -**	**$ 16,288**	**$ 394,909**

Figure 3: Results Summary Table showing the cost estimate for specific device distribution.

The intention of this main sheet is to allow the user to run a number of different "what-if" options to determine the cost impact of assigning different devices to different buses. In fact, by using either Microsoft Scenarios or a Visual Basic program, the system can search for optimal buses combinations for a fixed set of devices.

3.4 Application Results

Based on the devices counts provided by the company control engineers for a typical food plant, the authors ran a number of scenarios for different bus combinations. Device availability constraints and cost calculations quickly narrowed down the possibilities to a Foundation Fieldbus/DeviceNet combination or a Foundation Fieldbus/Profibus-DP/AS-i combination. For comparison purposes a traditional only design was also analysed.

As shown in Figure 4, the final results indicate that the choice of buses has relatively little impact to the overall project cost. The combined cost of materials, labour and commissioning are very similar for each of the four buses. The only noticeable impact may be on the engineering costs and on the maintenance costs as additional training and spares will be required for each new bus. The net result after considering the total installed cost is that installation of a mixed fieldbus system will result in project savings in the range of 30% over a traditional hardwired control system.

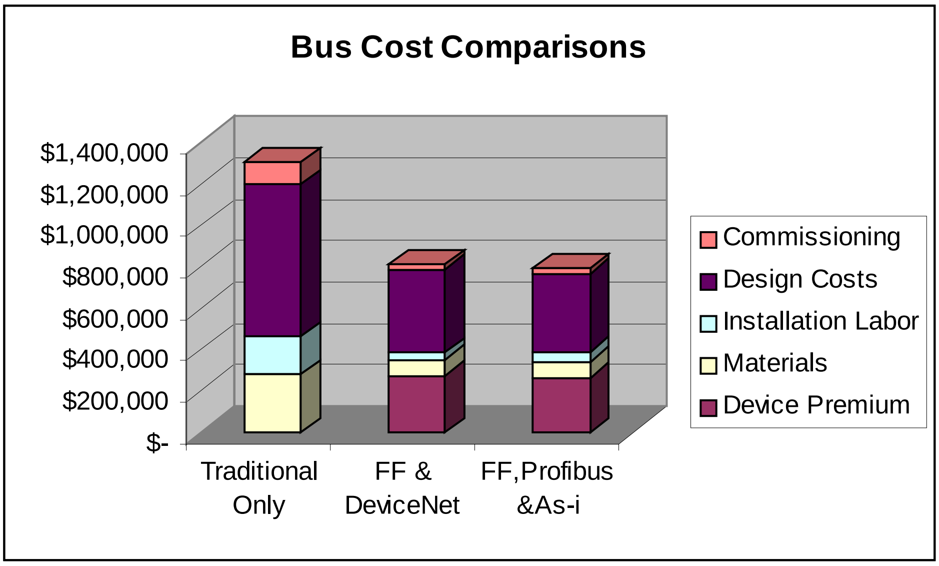

Figure 4: Results of Different Bus Combinations vs. Traditional

4. Cost Savings Not Included in the Model

It is important to understand that the above model provides information on the key cost variables at the start of a project but not all long-term costs or savings once the project is complete. Typically understanding these project costs is necessary to convince a cost-conscience project manager or approval committee. The model does not; as of yet, consider the larger benefits realizable over the life of a project. To help understand these costs, the use of literature searches and interviews with users of bus systems was undertaken.

Just like the familiar “Pareto Principle,” 80% of the cost associated with any industrial purchase occurs **after** it has been installed. When considered for a moment, if device has a typical ‘life’ of 10 years once installed, any reduction possible related to the maintenance of that device will quickly become significant.

4.1 Maintenance

The interviews with users in ten different industrial facilities indicated that all fieldbus systems reduced maintenance costs because they incorporate some level of device diagnostics. Even AS-i has this capability, though the level of detail is limited. Device maintenance information and bi-directional communications makes it possible for maintenance technicians to determine the ‘problem’ with a device before going to the field and in some cases, even negate the need to go into the field.

A study by Verhappen[h] quotes NAMUR Study Group 3.5 report indicating a savings of 20% in maintenance support and 40% in inventory as a result of using fieldbuses. Fisher-Rosemount reports a study showing that in one large chemical plant, 63% of the trips to the field to check transmitters were unnecessary. An additional 20% of the checks resulted in calibration changes (span and zero). With digital communications, up to 83% of these field trips would disappear with the use of the integrated computer based maintenance software on the host control system. In most sites this would result in a 15% savings on instrumentation maintenance costs[i].

4.2 Construction Cycle

User interviews and published literature[j] [k] indicate that the use of fieldbus technology results in up to a 90% reduction in the commissioning and start-up time of a control system. Since the control system is normally one of the final major systems to be commissioned, any time saved here will result in additional production from the process. Depending on the production rates and price of the plant, this can quickly accumulate to a significant revenue increase for the facility owner.

4.3 Long Term Support

All the major instrument manufacturers and host system suppliers are migrating their products to support fieldbus and digital networking. As a result, by the end of the decade tradition analogue devices will be a niche product and hence the most expensive systems to maintain. Such systems and devices are like to require the use of “hand made” boards because the chip sets on which they are made will no longer be available.

Fieldbus systems on the other hand will be the norm and since they are 'all digital' it will be possible to keep them current by simply installing the latest software upgrade. This is definitely the way to get the greatest benefit at the lowest price.

4.4 Technology Life Cycle

Like anything else, control systems have a life cycle, typically 10 to 15 years. Does it then make sense to start a project today that will be obsolete if not when it is commissioned, it certainly will be part way through its life cycle?

As was stated by Duncan Schleiss at Jump Aboard 2001,

> *"The challenge faced by host suppliers today is that hardware (chip sets) and operating systems have a 3 year life, while support for these systems is 10 — 15 years."*

In most cases this means it becomes the system suppliers responsibility to either provide the support, or for the end users to acknowledge a shorter life cycle for their control system.

Digital networks protect this investment to some extent since as long as the CPU and memory are sufficient, the software can be changed by download to the device.

The greatest opportunity lost by not using a digital control system is integration of information throughout the enterprise. If "knowledge is power" then digital control systems are the "path to power" since they make it possible for an organisation to know what is happening right down to the sensor level of the process.

5. Conclusion

As has been shown, fieldbus technology provides many benefits over conventional analogue devices at lower cost. A method is now available to assist in determining the degree of those benefits.

Once again it can be said that fieldbus systems make it possible to do things cheaper, faster, and smarter. Not just today, but for many years to come.

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