Aerospace ID

AUTO-ID LABS

ROI from Auto-ID Deployment in Aerospace Logistics

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Report Abstract: This paper presents results from investigation performed within the Aerospace Identification Technologies Programme into methods for business case analysis and return on investment models. It focuses on aerospace logistics, as requested by Programme sponsors, and looks more specifically into the benefits from improved Tracking and Tracing to inventory management and decision-making in industrial operations. The research builds on previous work carried out within the Programme, yet its main contribution is the introduction of decision trees to the ROI analysis process. These are used as a tool for understanding and taking risk into account when designing the adoption path for automatic identification technologies.

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1. Introduction

1.1. Aims

When considering the adoption of automatic identification technologies as process enablers, one of the inevitable questions asked by companies is about the *return on investment* (ROI) that they should expect. And although this has been among the most commonly asked questions, it has also been the most difficult to answer in a convincing way.

Net Present Value (NPV) is now a widely accepted instrument for the assessment of expected returns from investment projects. Yet when it comes to evaluating the deployment of new technologies such as RFID, users of NPV are faced with its greatest shortcoming: it does not take into consideration opportunities for management intervention and redirection as the project unfolds.

The aim of the present study is to introduce *decision trees* as a means to circumvent this shortcoming of NPV when it is used alone. It proposes a tool that enables decision makers to design the best path to automatic identification deployment, that is, one that takes into account how risk-prone or risk-averse their company is.

1.2. Approach

The authors sought to build the analysis on credible data obtained from sponsors of the Aerospace Identification Technologies Programme. Typical costs and benefits were obtained from aerospace end-users and solution providers, in order to create a basis as realistic as possible, from which to assess the usefulness of decision trees. Then a set of alternative paths for technology deployment were created and their relative risks and rewards compared through results obtained from the decision trees.

1.3. Report structure

This report is designed to take the reader through a logical sequence of steps as the analysis is set up and carried out. It is intended to be a guide for future application of the proposed ROI analysis process, so that readers are able to utilize the method in their own particular case studies. One should notice that section 7 is a side step in the sequence in order to justify the use of decision trees in ROI assessment, and is not a part of the analysis itself. Figure 1.1 presents the steps and report structure in a graphical format.

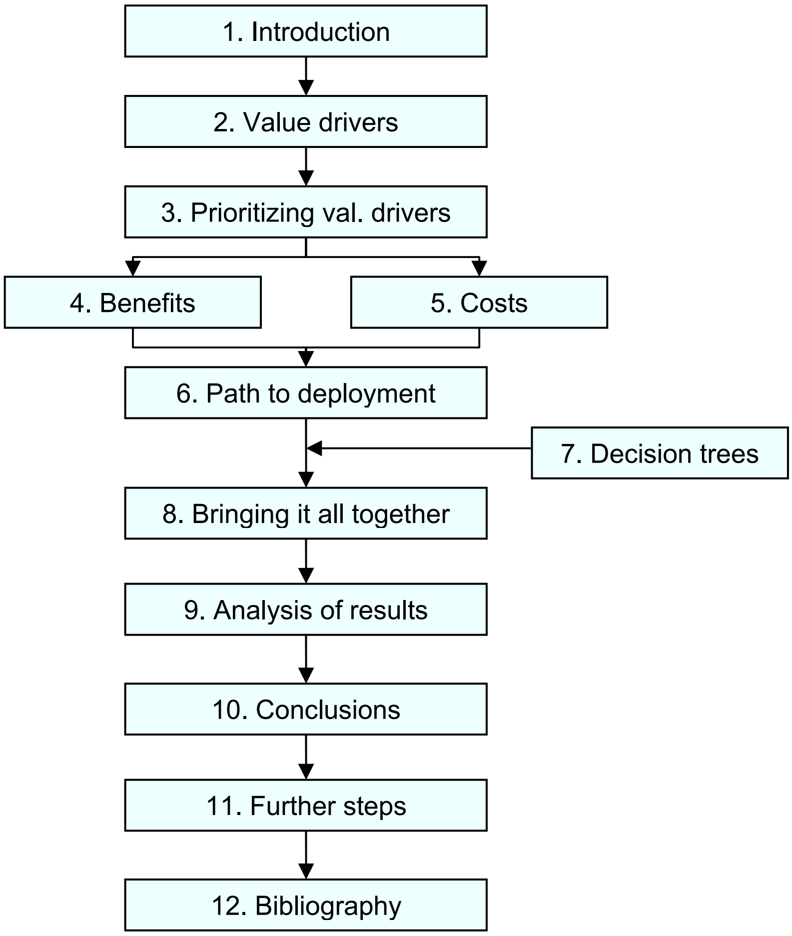

Figure 1.1: Report structure and sequence of analysis

2. Value Drivers in Aerospace Logistics

2.1. Overview

Consultations with sponsors of the Aerospace ID Programme indicated their preference for an analysis of ***logistics processes*** within the aerospace industry, which then became the focus of the work reported here.

A broad review of the literature available on ROI from auto-ID projects was conducted as a first step. The review material included academic publications, white papers from consulting organizations, presentations from auto-ID industry events, work sponsored by standardization bodies, and web-based ROI tools developed by a variety of organizations. The most relevant sources are listed in the Bibliography section of this report.

Most of the reviewed literature focused on estimated percentage reductions in costs or percentage improvements in process performance, with scarce mathematical substantiation of the claims. There is nevertheless reasonable agreement between the various sources as to which areas of industrial logistics would benefit from auto-ID. These are presented and described in the following paragraphs as ***value drivers***. This section addresses these drivers qualitatively, whereas Section 4 provides quantitative measures of benefits from selected drivers.

It is important to note that by ***industrial*** logistics we mean the part of logistics associated with the ***inbound*** supply chain to the aircraft manufacturer, before the aircraft is first rolled out of the plant. It does not mean the after-sales part associated with maintenance and spare parts, although several of the listed value drivers may apply equally to both contexts.

2.2. Inventory-related value drivers

2.2.1. Inventory turns

In financial terms, inventory is regarded as immobilized capital. In other words, it represents money that is 'sitting on shelves' instead of yielding interest at some other more attractive form of investment. Therefore it is generally desirable to optimize the size of inventory by reducing the amount of goods in stock to the minimum necessary.

Inventory turns are a well-established measure of operational efficiency; they measure how much inventory a company needs in order to maintain its industrial output. It is given by the ratio:

$$\frac{\text{Cost of goods sold}}{\text{Capital immobilized as inventory}}$$

Let us consider the following situation for comparison:

- Company A produces 100 aircraft per year and, to do so, keeps inventory equivalent to 15 aircraft in its warehouses at any time. It operates at ***6.7*** inventory turns per year.
- Company B is a competitor that also produces 100 aircraft of equivalent price per year, but needs inventory levels slightly larger to do so, at 20 aircraft. Company B turns its inventory ***5.0*** times per year.

So Company B is less efficient than Company A.

Auto-ID technologies provide better visibility of goods being moved or stored within logistics and manufacturing processes, and enable optimization of inventory levels against a desired industrial output.

2.2.2. Safety stock

This is the minimum level of inventory that must be kept at any time to ensure that production will not be disrupted by out-of-stocks. Safety stock is calculated as a function of the ***rate*** at which parts are consumed by production (demand), of the ***time*** it takes suppliers to deliver a new order of parts (lead time), and also of the ***variability*** in these two factors.

A typical cause of safety stock increase is the lack of visibility across the boundaries between organizations in a supply chain. This causes individual companies to build their own safety buffers of materials or goods in order to protect them from unforeseen variability in the supply from upstream or demand from downstream. Since little or no information is shared about stocks being kept by the other players, the net result is typically a much larger total amount of goods being kept within the chain than is actually necessary. The propagation of variability and uncertainty along the chain gives origin to a well known phenomenon: the “bullwhip effect” (*Hijjar et al, 2003*).

Safety stock is an important issue in aerospace and will be revisited in Section 4.

2.2.3. Discarded inventory (surplus)

These are items in stock that can no longer be used by manufacturing due to obsolescence, having exceeded their expiry dates, having been rendered unsuitable by damage or mishandling. Auto-ID technologies provide better tracking of such items, especially in the first two cases where information about time and location will determine the usability of the items.

2.2.4. Shrinkage

The term applies to inventory that has been stolen, misplaced or lost in transport, and is considered as irretrievable. As in the case of surplus, this is a potential target for auto-ID enabled tracking and tracing processes.

2.2.5. Out-of-stocks

This refers to a situation in which the required products or goods are not available for prompt use due to incorrect provisioning, poor forecasting or unforeseen disruptions in the supply chain. Aircraft manufacturers will typically incur substantial financial penalties for not delivering their products to clients as scheduled, not to mention the damage caused by lateness to their reputation in the market. In many circumstances higher than optimum inventory levels is tolerated in order to avoid late deliveries caused by out-of-stocks in aircraft components. Once again, these industrial processes can benefit from improved tracking and tracing provided by auto-ID.

2.3. Time-related value drivers

2.3.1. Replenishment cycle time

This is the total time elapsed between an order being placed to a supplier and its delivery to the client. It assumes that the finished goods are *in stock* at the supplier, and no further manufacturing takes place before shipment. Suppliers operating in this manner are said to *build-to-stock*. Better warehouse management as well as efficient order processing are typical benefits brought by auto-ID technologies to this context.

2.3.2. Lead time

Lead time is the total time required by a supplier to deliver a finished product, from setup and manufacturing, to order processing, through transportation and final delivery at the client site. In this case there will be additional *manufacturing* steps prior to shipment, different from replenishment time mentioned previously. Suppliers operating in this manner are said to *build-to-order*.

Lead time = Manufacturing time + Replenishment time.

2.3.3. On-time deliveries

Deliveries made within the time constraints agreed upon by contract are accounted for as being on-time. This is a key performance indicator in supply chain management, and one that can make or break commercial relationships between companies. Aircraft manufacturers place significant importance on their deliveries being on time, as discussed previously for *out-of-stocks*.

2.4. Decision-support value drivers

2.4.1. Supply forecasting

The source of benefits here consists of better matching between logistics management and manufacturing management. Higher levels of visibility into both the manufacturing floor and the supply chain can help optimize transportation costs given the level of urgency with which goods are needed. Modes of transportation can be changed on short notice to speed up delivery of parts to the plant, and thus avoid out-of-stocks.

Supply forecasting has been identified as another critical issue in aerospace logistics, and will also be revisited in Section 4.

2.5. Handling efficiency value drivers

2.5.1. Labour efficiency

Impact from auto-ID on labour is obtained from reducing the amount of man-hours required for the same amount of work to be completed. In aerospace logistics this can typically be achieved at receiving docks, inspection areas, warehouse management, shipment tracking and order picking, to name a few.

2.5.2. Billing precision and invoice adjustments

In simple terms, this value driver involves better matching between what has been ordered and what has actually been delivered to the customer. Sponsors of the Aerospace ID Programme report that it is not uncommon to encounter inconsistencies in up to 20% of shipments being received at aircraft manufacturers in the course of a typical month.

2.5.3. Detention costs

These are costs incurred when goods are kept in the custody of customs beyond what would normally be required. A typical cause is a mismatch between documentation and actual shipment contents, which can be circumvented with automatic shipment reconciliation prior to international transportation.

2.6. Other value drivers

2.6.1. Liability and warranty costs

A less publicized aspect of the aerospace industry is the high premia paid by manufacturers to insure themselves against liabilities arising from the operation of their products. Even though civil aviation holds the best safety record within the transportation industry, accidents have a very high profile in the media and related law suits attain tens of millions of pounds in compensation and punitive charges. Manufacturers are invariably drawn into such disputes and have to actively prove their innocence. Better processes and quality control – as in auto-

ID enabled part pedigree – will have a positive impact on these insurance costs. A similar impact can be expected on warranty costs due to better lifecycle management and component history tracing.

2.7. Summary

The return on the investment made in auto-ID deployment will come from improvements obtained in any combination of the areas mentioned above. It is important to notice that these value drivers may be given different relative importance by different companies, and may even be weighed differently by the same company at different stages of its life. Therefore prioritizing the value drivers according to current criteria becomes the next logical step of the analysis.

3. Prioritizing Value Drivers

The list of value drivers obtained in the previous section was validated with sponsors of the Aerospace ID Programme. Aircraft manufacturer Embraer was then asked to prioritize the value drivers by order of importance to its own industrial operations. The particularities of internal processes in Embraer, in association with its current phase – having recently launched a new family of aircraft – established the basis for building the ROI analysis.

It was found that the two most significant sources of potential benefits to Embraer in 2007 are in improved ***inventory management*** and in better ***decision support*** between logistics and manufacturing. Returns in these two areas are estimated to be at least one order of magnitude higher than those from any of the other value drivers.

Here are a few considerations to help understand the rationale behind the selection:

- The Brazilian manufacturer is no different from Boeing or Airbus in that it is part of a global and complex inbound supply chain. There is a constant flow of components from North America, Europe, Asia and Brazil itself to the plants in São Paulo. Tens of millions of US dollars in goods pass through its receiving docks every month.
- Total inventory as a percentage of annual revenues is a well established performance indicator at Embraer, and one that has received growing attention in recent years.
- The company has recently launched a new family of regional jets, ranging from 70 up to 110 passengers in capacity. The supply chain for this family is still undergoing a process of stabilization after a steep learning curve, so further improvement is still possible in overall inventory levels.
- Aerospace parts and components are significantly more expensive as compared to other industries such as consumer goods. Furthermore, aircraft configuration can vary significantly from one client to another, and total volume of specific part numbers (types) can be low. These factors cause some suppliers to operate on a build-to-order basis, which brings added challenges to the coordination of logistics.
- Embraer sees a competitive advantage in its agility to reconfigure the industrial infrastructure and to rearrange its production plan in order to accommodate fluctuations in demand. It is possible for new orders of aircraft to take precedence over older ones if the correct balance between added revenues and late penalties can be achieved. Given this dynamic scenario, better matching between logistics management and production management is highly desirable, and would benefit from improved tracking and tracing systems.
- Transportation modes, and therefore costs, will be rearranged to accommodate or to prevent disruptions in manufacturing. For instance, a shipment of parts that is

overdue and originally scheduled for sea transport to Brazil can be diverted and flown into the country instead. This is currently a labour-intensive process that can also benefit substantially from auto-ID deployment for accurate tracking.

- The company buys components and sells aircraft in US *dollars*, but pays salaries to most of its employees in Brazilian *reais*, at local labour market rates. This contributes towards decreasing the relative importance of labour efficiency benefits.

The following section provides a quantitative assessment of the benefits expected from auto-ID deployment to support these processes.

4. Typical Benefits from Auto-ID Deployment

The goal of this section is to determine credible quantitative input for the analysis with decision trees, and for that a typical case was designed around a fictitious (yet representative) aircraft part. It is not the objective of this section to exhaustively examine possible sources of financial benefits from auto-ID enabled processes in logistics.

4.1. Improved inventory management

Inventory in aerospace can take several forms such as safety stock, work in progress, quarantined items and spare parts, just to name a few. We choose to focus here on *safety stock* for the sake of simplicity, and propose the following case as being typical. We assume that:

- Our chosen part costs US$ 15,000
- 4 such parts are needed for each aircraft produced
- The monthly production rate varies from 6–8 aircraft as per Table 4.1. This is a characteristic of annual operations at Embraer, where the second semester is typically busier
- Supplier lead times vary from 70–100 days as per Table 4.1. The overall variability here is typical, although not necessarily neatly distributed along the year. The important requirement for the goal of our analysis is that the standard deviation be accurate
- Desired service level is 99%, which means that the safety stock should ensure that demand is met in 99% of the circumstances
- Safety stock for this part is currently kept at 42 units, based on experience

These assumptions were compiled into Table 4.1 to build a representative scenario of annual operations.

Month	Lead time (days)	Demand (parts/day)	Demand (parts/month)
Jan	70	1.00	24
Feb	70	1.00	24
Mar	70	1.00	24
Apr	70	1.00	24
May	70	1.00	24
Jun	70	1.00	24
Jul	80	1.00	24
Aug	80	1.17	28
Sep	95	1.17	28
Oct	95	1.17	28
Nov	100	1.33	32
Dec	100	1.33	32
STDEV	12.94	0.13	
AVERAGE	80.83	1.10	

Table 4.1: Typical case for annual part usage

The optimum safety stock under these circumstances (*Dighero et al 2005; Lee & Özer, 2005*) would be given by the equation:

$$\text{Optimum safety stock} = k \,.\, \sigma \qquad (1)$$

Where σ is the overall process variability given by:

$$\sigma = \sqrt{LT \cdot \sigma_D^2 + D^2 \cdot \sigma_{LT}^2} \qquad (2)$$

and calculated from the average values for *lead time* and *demand* together with their standard deviations, as presented in Table 4.1.

k is a *service level* factor, as explained previously, and given by:

service level	k
60%	0.3
80%	0.84
95%	1.65
99%	2.33
100%	4

Manufacturers do not normally have information systems that keep timely track of such process variability with the granularity and timeliness required for equations (1) and (2) to be employed. Obtaining the numbers is usually a manual chore carried out in hindsight, weeks or months after the fact. It requires exchanges of information with suppliers whose systems are not integrated with those at the aircraft manufacturer. For these reasons we will consider that safety stock cannot be currently optimized to the 33 parts indicated by the calculations. An auto-ID enabled Track and Trace system would provide the performance needed for such timely inventory adjustments, and the *annual benefit* to be obtained from this system would be given by:

reduction in part inventory x unit cost of part

(42 – 33) x 15,000 = ***US$ 135,000***

We will consider this figure as typical for each of the various types of parts being monitored by an auto-ID enabled system.

4.2. Better decision support

The role of improved Tracking and Tracing systems in decision-support has been extensively explored in previous reports produced under the Aerospace ID Programme (*Kelepouris et al, 2006–07*). In those studies it was shown that it is possible to quantify in monetary terms the benefits obtained from employing an auto-ID enabled system each time a decision has to be made. The focus of that work was on logistics, and more specifically on decisions about the preferred mode of transportation for a shipment of components, given the level of urgency it has for manufacturing.

It is beyond the scope of this paper to reproduce the calculations available from these previous reports. They can be accessed from the Auto-ID Labs repository at *www.autoidlabs.org*. For current purposes, it is sufficient to know that an approximate ***US$ 2,000*** benefit per decision (that is: per monthly shipment) was calculated for a typical part shipment at Embraer. This figure will be utilized in our analysis in addition to the annual reduction in safety stock obtained in section 4.1 above.

This section presented quantitative measures of benefits expected from auto-ID deployment in aerospace logistics. These benefits, of course, come at a price. The costs of setting up the infrastructure and running the improved Tracking and Tracing systems that will provide the benefits are explained in the next section.

5. Total Cost of Ownership

Consultations with end-user Embraer indicated that RFID would be the auto-ID technology of choice for the logistics processes described earlier. The proposed infrastructure would basically consist of:

- a portal with antennae and RFID reader at the main plant's receiving dock;
- a similar setup at the supplier's expedition dock;
- a pair of portals at the freight forwarder who is responsible for transportation between the two facilities mentioned above; and
- the information systems and hardware at each of these players.

A simple schematic representation is given by Figure 5.1.

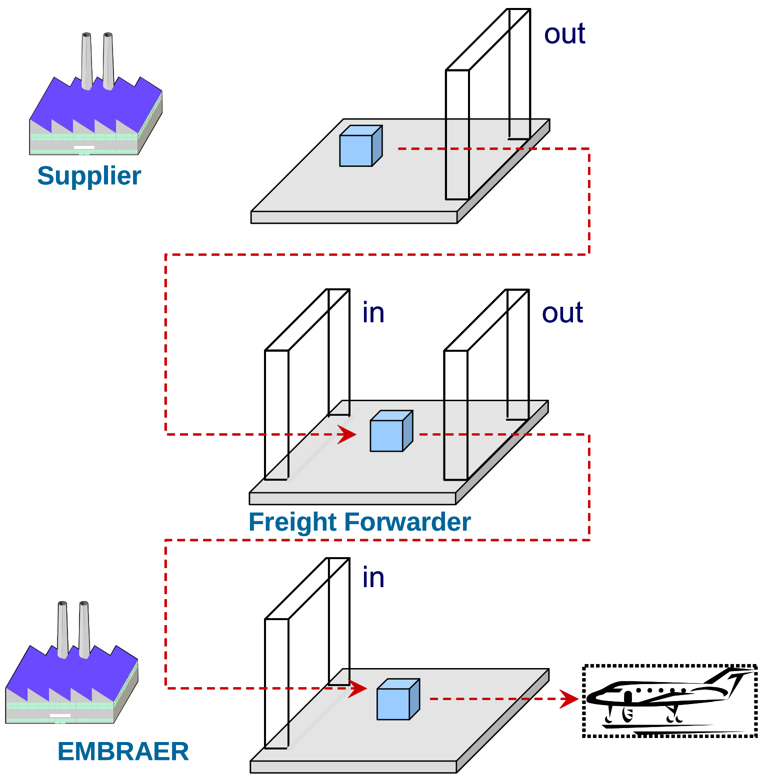

Figure 5.1: RFID infrastructure layout

Clearly, more infrastructure would be necessary if other suppliers and/or freight forwarders were to be added to the auto-ID enabled supply chain. Conversely, more value would be obtained from leveraging the same enabled forwarder across various suppliers. For the sake of simplicity in our calculations, we will assume that each new supplier will also require a new investment in infrastructure at a freight forwarder.

A ***total cost of ownership*** model should be used to assess the level of investment, maintenance and operation expenses needed to create and run the improved Track and Trace system. Figure 5.2 presents a complete view of the various costs involved, as it is currently practiced by major IT systems integrators.

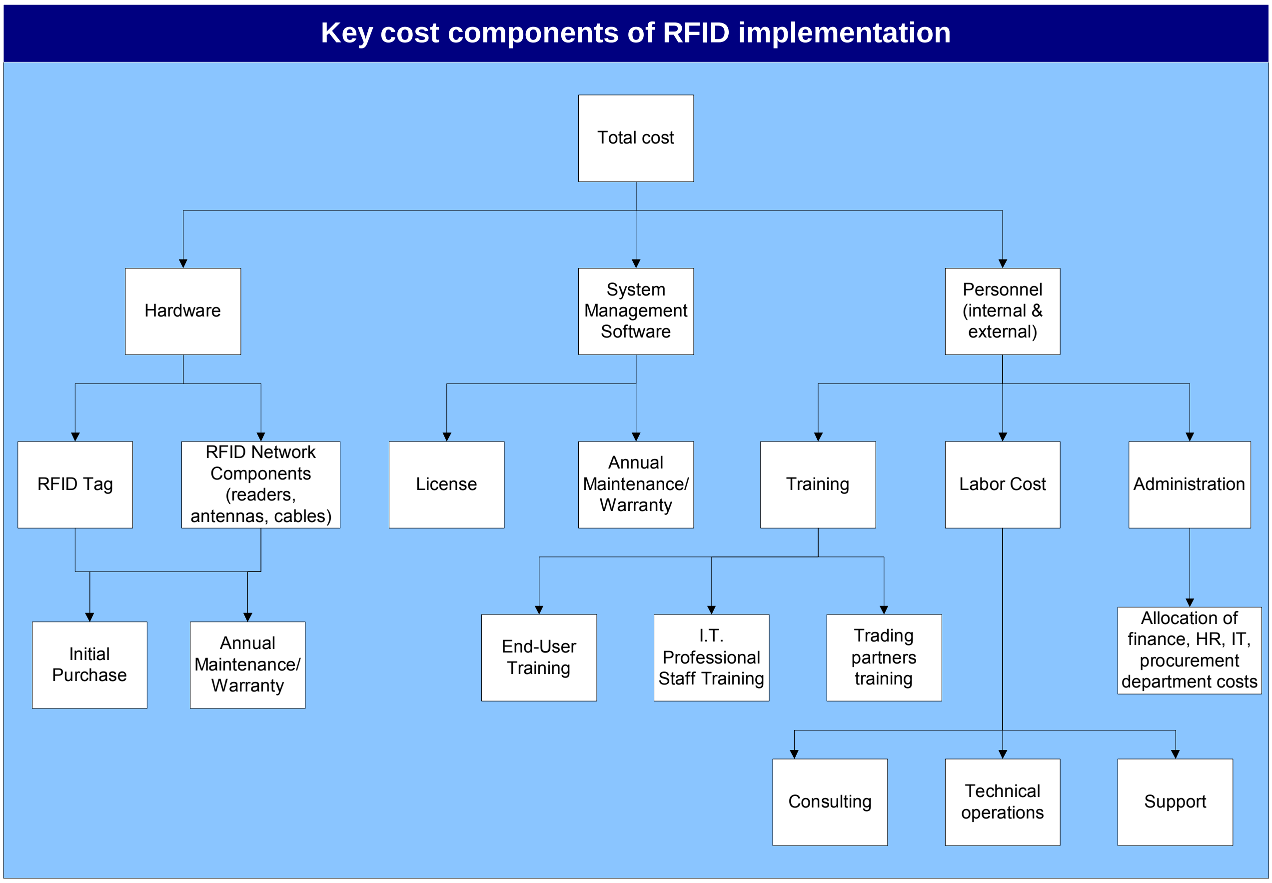

Figure 5.2: Total cost of ownership model (*Shankar, 2006*)

Details from the cost calculations are omitted here in order to protect the internal practices of Aerospace ID Programme sponsors. Table 5.1 contains the results divided into two stages: the first one in which only a receiving dock portal and IT system is utilized at the main plant, and a second stage in which the remainder of the infrastructure is added at the supplier and freight forwarder, and their systems are linked together.

Stage	Costs *(US$ thousand)*		
	Initial min	Initial max	Maintenance & operation*
Receiving dock + IT system	*72*	*117*	*38*
Supplier and freight forwarder	*129*	*169*	*42*

* annual (recurring)

Table 5.1: Total cost of ownership for RFID enabled system

The reason for the use of this multiple stage approach will become explicit in Sections 6 and 8, when we address the issue of running pilots as part of the deployment process.

5.1.1. Narrow margins

From Section 4 we obtained an expected annual benefit of US$ 159k per part type ($135k from safety stock plus $24k from 12 shipment decisions at $2k each). When comparing these numbers against the figures in Table 5.1, it becomes evident that the *net* benefit to be gained from monitoring one individual part type is small. In order to justify the learning effort around a new technology, and the associated process and systems changes, the benefits will have to be compounded across several part types. The individual margins from multiple part types will have to be added together in order to build an attractive deployment project in which a large aerospace company would be willing to invest.

6. Building a Path for Deployment

Now that the most significant benefits have been identified and the associated costs tallied, the next step becomes one of defining the implementation path. In other words: how should deployment of the new RFID technology be carried out so that the expected benefits can materialize? Should it be rolled out across several part types and suppliers simultaneously, in order to quickly build significant benefits? Or should a more cautious approach be taken, considering the lack of experience with RFID?

Figure 6.1 illustrates two different ways in which the deployment project can be structured. Undoubtedly, if we take into account only the *time value of money* – the underlying principle of Net Present Value calculations – then the second approach seems less attractive.

	year 1	2	3	4	5	6	7
part A	(-)	+	+	+	+	+	+
part B	(-)	+	+	+	+	+	+
part C	(-)	+	+	+	+	+	+
part D	(-)	+	+	+	+	+	+

NPV = **1000**

	year 1	2	3	4	5	6	7
Internal PILOT, part A	(-)						
PILOT between sites, part A	(-)	+	+	+	+	+	+
External PILOT, part B		(-)	+	+	+	+	+
part C			(-)	+	+	+	+
part D			(-)	+	+	+	+

NPV = **700**

(-) investment + benefit

Figure 6.1: Full scale deployment versus a staged approach

But experience accumulated from across the many industrial sectors in which auto-ID technologies have been successfully deployed indicates that the best course of action to be taken in these early phases of innovation adoption is a staged one. Companies will be more receptive to experimenting with innovation if it is carried out in incremental phases that keep costs and capital expenditures under control.

The few tools available for calculating ROI in auto-ID have employed Net Present Value (NPV), which typically yields a single, static figure resulting from projected cash flows or cost reductions. Such tools do not take into account the *risk* and *uncertainty* associated with those estimated cash flows, nor the benefits stemming from a *staged* investment approach. They do not account for the knowledge gained in incremental steps, which can significantly improve the decision-making process for the ensuing phases. As a result, companies tend to be sceptical about pure NPV assessments of auto-ID, and a natural course of action becomes to postpone adoption.

Fortunately, there is a way to overcome the shortcomings of NPV in the assessment of such projects.

7. Decision Tree: A Tool for Risk Assessment

7.1. Overview

Most organizations will find it difficult to decide about a large-scale investment in innovation when their understanding about the new technology is still incipient. If the investment can be spread across budgeting cycles, with one or more intermediary decision points in between, then companies will become more comfortable with the idea of risking some of their cash into innovative work around process improvement.

These investments, the associated decision points, their costs and benefits can all be arranged into a *Decision Tree* as illustrated in Figure 7.1. A decision tree is a simple way to record and represent the possible future of a project including the decisions that may be taken along the way. It allows managers to explore the various possibilities facing the project and to come to an overall assessment of its value in the light of the possibilities. The square boxes represent phases of the project, which may involve expenditure (−£) or income (+£).

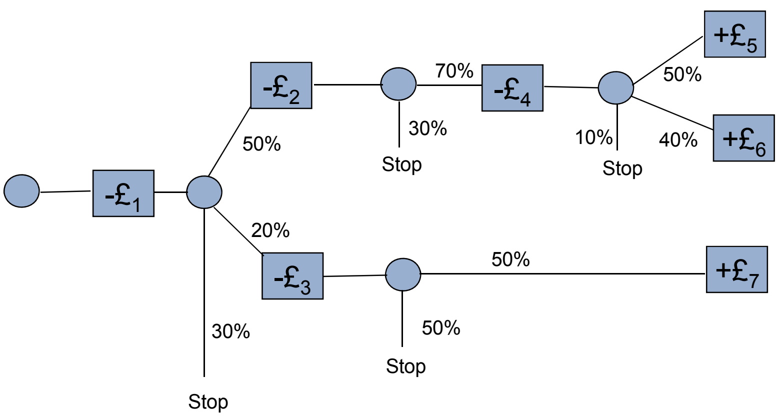

Figure 7.1: Simple example of a decision tree for a project

The circles are branching points at which a decision may be made whether, or how, to continue. Probabilities (or, more correctly, *confidence levels*) are assigned to each branch as shown. Such a decision tree can include everything that is known – or speculated – about the possible future of the project, and expressly includes the complete range of likely outcomes. As we know, the analysis is only as good as the information that goes into it and, indeed, decision trees are often criticised because they may include unreliable information. The advantage, however, is that in building the tree, managers make explicit what they do and do not know. Analysis of the tree will at least give as complete a prediction of the financial value as is possible with the information available (*Hunt et al, 2003−2004*).

The key issues are as follows:

- How best to obtain the information to be included in the tree?
- How to analyse the tree to obtain a prediction of value, and use it to select or compare projects?

7.2. Obtaining the information

Reliable information on the costs and probabilities required for the tree may be difficult to come by especially if the project has a high level of novelty. So, to some extent, decisions must be based on subjective judgments. The question is how best to manage the process by which essentially subjective judgments from several individuals are combined into a 'best view'. Empirical research has shown that subjective judgments by individuals are notoriously subject to bias arising from lack of knowledge, wishful thinking and personal characteristics such as risk aversion. But judgments by groups are also prone to errors arising from group dynamics, politics and undue influence by forceful or powerful members.

The proposed process, which seeks to combine the merits of individual estimating and group work, is described in the following sections.

7.2.1. Structuring the problem

As a first step, it is often helpful to break an estimating task into its component parts and estimate them separately. For example in finding a lost ship, the search team is typically asked to make separate estimates of the position where it sank, its bearing, speed, angle of descent, etc. rather than just their estimate of the final position. The separate results are then combined in a model to give a best prediction of its position.

We typically use a group meeting to agree the structure of the decision tree and how the individual elements might usefully be broken down. This meeting may also identify and share information that everyone may need in making their estimates.

7.2.2. Individual estimating

Participants are asked to make their own estimates separately before any detailed group discussion takes place. This process encourages everyone to think carefully about the topic and to formulate and define their views before being exposed to the influence of others. It also helps to ensure that everyone takes the task seriously.

When estimating quantities, participants are asked to give upper and lower estimates, rather than a single value.

When estimating probabilities (for instance, the probability of technical success) precise figures are difficult to obtain and justify. Indeed people often (rightly) find the idea of the probability of a single event difficult to understand and quantify. An effective approach is to ask participants to decide how they would apportion a wager of 8 (or 6) points among the outcomes (for example, 4-4; 3-5; 2-6; 1-7). This asks people for an indication of their confidence in the choice rather than a judgment of probability; and it restricts choice to an appropriately coarse 7- or 5-point scale.

7.2.3. Group discussion and consensus

Final decisions are made at a group meeting. The facilitator presents the individual estimates anonymously and the team debates the values and agrees on a consensus. The facilitator must keep the discussion objective and fact-based as far as possible. If there is difficulty in avoiding undue influence from powerful individuals, the facilitator may ask participants to review their estimates in private, and then take an average.

7.3. Analyzing the decision tree

Monte Carlo analysis can be used to plot the range of values implied by the decision tree. A simple software tool is available at the Centre for Technology Management that allows this to be done quickly and simply. The result is a Confidence Distribution of Value, such as that shown in Figure 7.2. This is the prime output from the process and may often prompt a re-examination of the plan to minimize the risk of poor outcomes and enhance the possibility of good ones. (Managers may wish to disregard the tails of the distribution as being too unlikely to be worth considering).

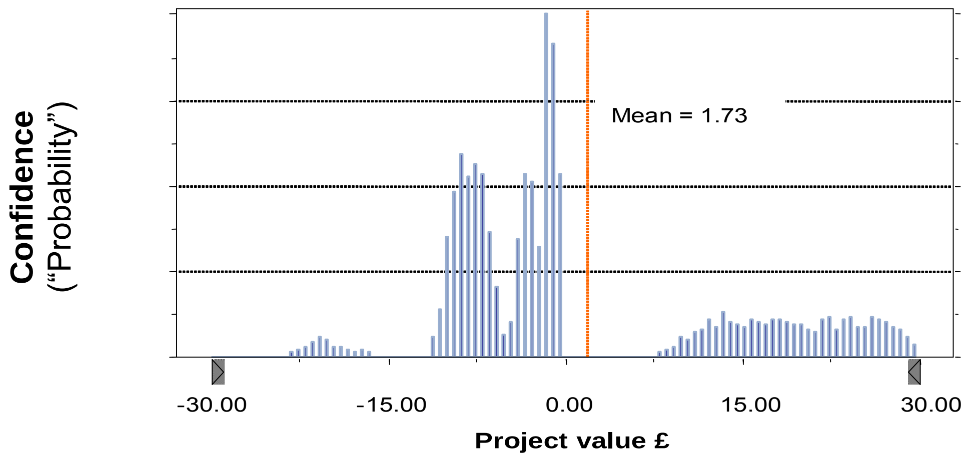

Figure 7.2: Monte Carlo plot of project value from a decision tree

Decisions may be made between competing projects on the basis of the balance they offer of probable loss against gain, or of possible downsides and upsides in relation to a benchmark, such as return on investment or cash at risk.

8. Bringing it All Together

8.1. Pilots

Further discussions with Embraer indicated that the following *pilots* (or *trials*) could be built, and thus could establish the nodes of a decision tree in the path for RFID deployment at that company.

8.1.1. Internal Pilot

For Embraer, this would be its very first experience with RFID within logistics. It consists of a single RFID-enabled portal at the receiving dock where part ‘A’ arrives from its origin, together with the IT system necessary for automatic acknowledgement of arrival and invoice reconciliation. This pilot would require the parts to be simply tagged before shipment in a typical ‘slap-and-ship’ operation without any RFID enabled exchange of data between the companies involved. Furthermore, this pilot would not involve an RFID infrastructure at a freight forwarder.

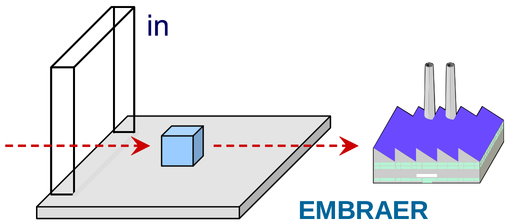

Figure 8.1: Internal Pilot

The benefits to be obtained from this pilot would come mostly from the practical knowledge of RFID it would provide to the staff involved and, to a lesser extent, from a few man-hours saved from inspection labour at the receiving dock. This infrastructure would not be sufficient to bring the benefits from better decision support or reduced safety stock. We will assume that, after the initial investment of US$ 72,000 to 112,000 (from Section 5), the small labour savings would offset the operation and maintenance costs, and thus the net financial benefit would be zero in the ensuing years. Nevertheless, the knowledge gained with the pilot would influence the confidence levels within the decision tree, as we shall see in the sections ahead.

8.1.2. Pilot Between Sites

The next pilot would complement the first Internal Pilot by building the RFID infrastructure and associated IT systems at the Freight Forwarder and at the Supplier of part ‘A’. We assume that the Supplier is at another industrial site within Brazil, so that no air or sea shipments across country borders are involved, but only domestic land transportation.

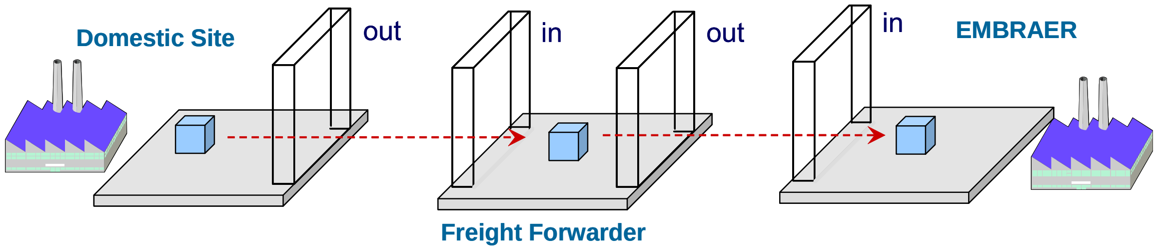

Figure 8.2: Pilot Between Sites

Benefits from optimum safety stock could then be achieved, as variabilities in the overall process can be accurately tracked by the RFID-enabled system. On the other hand, decision support for the choice of transportation modes is not applicable.

8.1.3. External Pilot

This would be similar to the Pilot Between Sites, in that additional infrastructure is built at the Supplier and at the Freight Forwarder. But now the Supplier of part ‘B’ is located overseas, so that the full benefits of better decision support regarding transportation can be added to the advantages from optimum safety stock. Slightly larger implementation costs are assumed, given this more complex configuration of the supply chain.

8.1.4. Full implementation

The ultimate goal of the pilots is to build knowledge and confidence leading to a full RFID implementation. We define this as a full deployment across the supply chain for six parts:

- part ‘A’, as described for the Pilot Between Sites, and
- parts ‘B’ through ‘F’, typified by the External Pilot.

8.2. Decision trees

The pilots described above were combined into three different decision trees, representing three different paths for RFID deployment towards a full implementation. The particularities of each tree are described next.

8.2.1. Three Pilots decision tree

Our first decision tree describes the path from an internal pilot to full implementation (Figure 8.3). In this case, the company first invests in the receiving dock and IT system, and then it operates the RFID system experimentally for a few months. Having gained experience and knowledge, it faces the 1st decision situation: To stop the Internal Pilot, to deploy internally on a permanent basis, or to deploy and extend the work into the next pilot level.

If the decision is made to deploy internally, then the expected financial return from RFID is obtained. At this stage it barely offsets the system’s operation costs, so NPV is *zero* (see Table 8.1). Otherwise, if it is decided to stop the pilot without further investment or operation, then the prior investment is lost. But the risk from additional losses can be assessed and avoided at this stage given the results obtained from the Internal Pilot test.

Moving into the next level, the investiture requires new portal docks and IT system extensions at the freight forwarder and domestic site only, because the infrastructure from the internal pilot is already in place. After this 2nd pilot investment, a similar decision situation is faced again: To stop, to deploy, or to deploy and move on to the final pilot stage. Deployment here means the possibility to decrease safety stock with improved visibility from RFID, which brings a real and measurable benefit.

Finally, another trial is conducted with an external supplier located overseas, prior to the ultimate decision about a full-scale deployment with five external suppliers. External deployment brings added benefits from decision support around transportation modes.

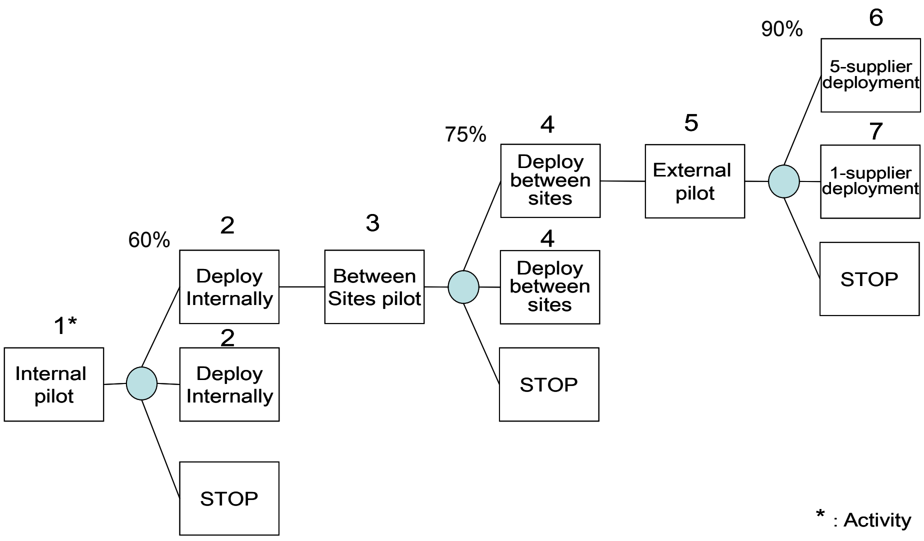

Figure 8.3: Three Pilots decision tree

Benefits and costs are presented as net present values (NPV, in US$ thousands) calculated over seven years, and they range from optimistic (maximum) to pessimistic (minimum) values. The difference between these two extremes is given by a one-year delay in obtaining results from the project. Activities 1, 3 and 5 presented in Table 8.1 are investments in the RFID infrastructure, therefore the numbers are negative.

The two fundamental assumptions for this model are that:

- every starting pilot has a 60% chance of conducting into the next level; and
- every pilot conducted increases the likelihood of success at the next stage by 15%.

Therefore running the 1st Internal Pilot is a means of increasing the likelihood of success at the next stage and of interrupting investments early, but brings no direct financial benefit.

Activity	Max NPV *	Min NPV *	Probability
1	*−72*	*−117*	Activity 2 then Activity 3 : 60%
2	0	0	Activity 2 : 5% STOP: 35%
3	*−111*	*−129*	Activity 4 then Activity 5 : 75%
4	414	317	Activity 4 : 5% STOP: 20%
5	*−126*	*−146*	Activity 5 then Activity 6 : 90%
6	793	475	Activity 7 : 5%
7	315	230	STOP after Activity 5 : 5%

* In thousands of US dollars

Table 8.1: Input for Three Pilots decision tree

8.2.2. Two Pilots decision tree

For this second scenario, the Internal Pilot is eliminated. So one would begin with the Pilot Between Sites at a 60% likelihood of moving forward, but at a slightly larger cost since the needed infrastructure is all built at once. This includes the internal dock and IT system at Embraer.

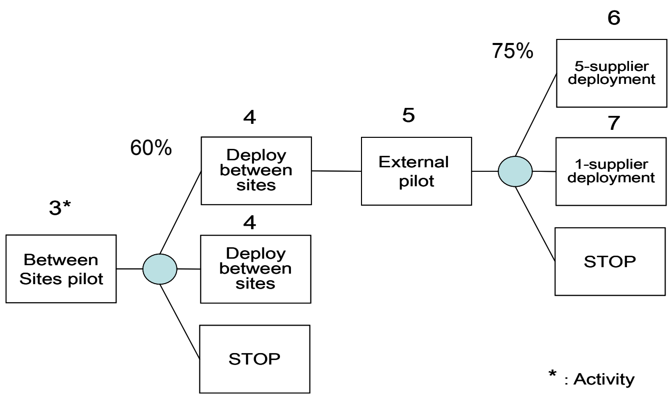

Figure 8.4: Two Pilots decision tree

Otherwise, NPV calculations and probabilities follow the same principles as with the Three Pilots decision tree.

Activity	Max NPV *	Min NPV *	Probability
3	*−183*	*−213*	Activity 4 then Activity 5 : 60% Activity 4 : 5% STOP after Activity 3 : 35%
4	414	317	
5	*−126*	*−146*	
6	793	475	Activity 5 then Activity 6 : 75% Activity 7 : 5% STOP after Activity 5 : 20%
7	315	230	

* In thousands of US dollars

Table 8.2: Input for Two Pilots decision tree

8.2.3. One Pilot decision tree

Finally, a third scenario is built with only one External Pilot and a 60% chance of proceeding to full deployment.

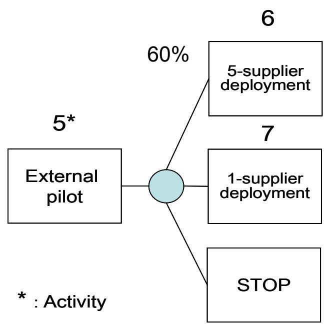

Figure 8.5: One Pilot decision tree

The NPV calculations and probabilities follow the same principles as before, with one very important exception. Since only one pilot is done, less time elapses and the benefits can now be obtained earlier, that is, from *the second year onwards*, as opposed to the third year in the previous scenarios. This has a significant impact on the NPV for the full deployment (Activity 6), as presented on Table 8.3. This comes as a consequence of the relatively high discount rate used in the calculations, based on Brazilian inflation to which Embraer is subject.

Activity	Max NPV *	Min NPV *	Probability
5	*−183*	*−213*	Activity 5 then Activity 6 : 60%
6	1162	793	Activity 7 : 5%
7	414	315	STOP after Activity 5 : 35%

* In thousands of US dollars

Table 8.3: One Pilot decision tree

Figure 8.6 summarizes the timing of investments and benefits along 7 years for each of the three scenarios.

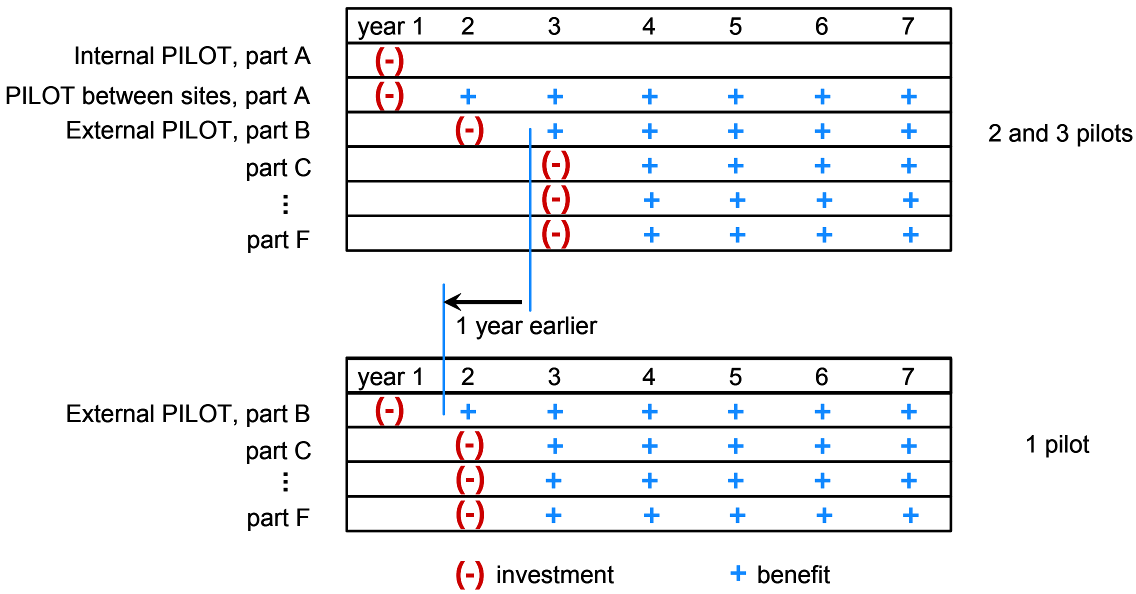

Figure 8.6: Time distribution of cash flows

9. Analysis of Results

9.1. Three Pilots decision tree

The *best* possible outcome (HLV) is a profit of US$ 898k, while the *worst* possible (LLV) is a loss of US$ 246k (a ratio of 3.6 to 1).

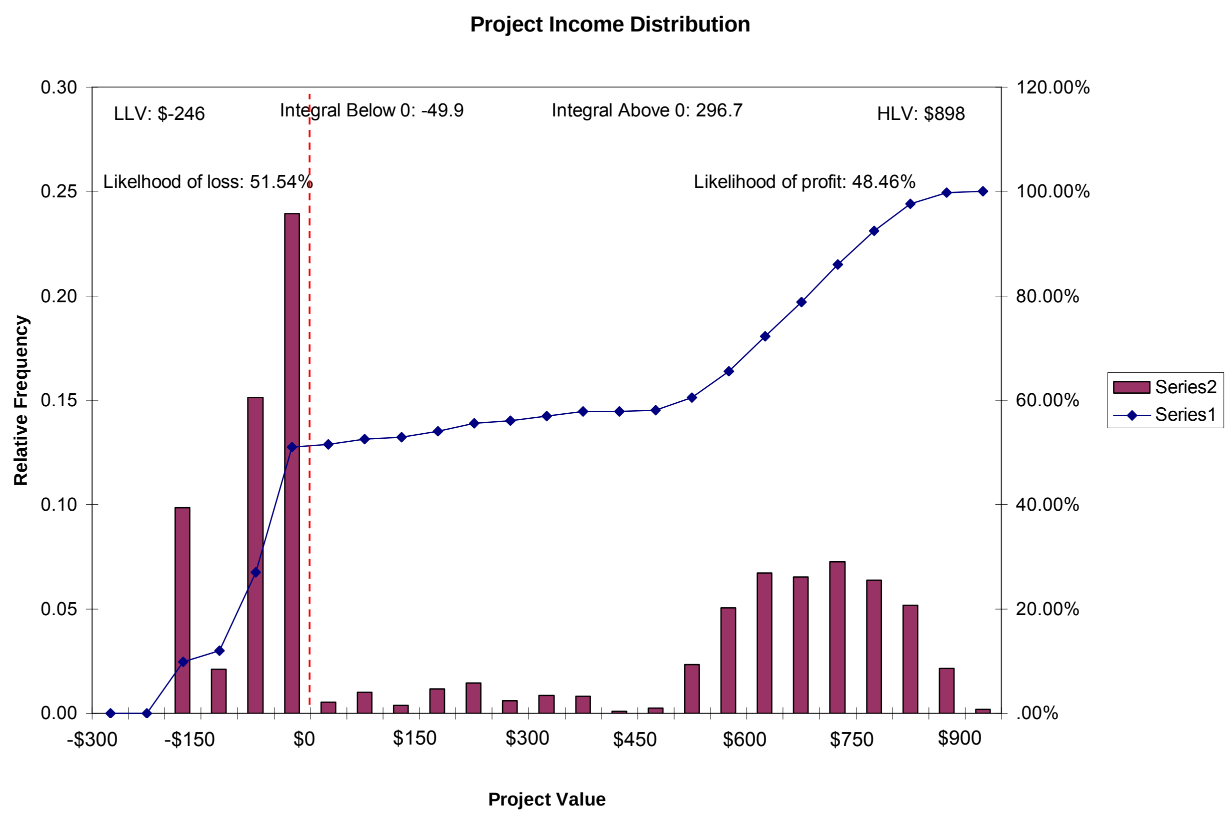

Figure 9.1: Income distribution, Three Pilots

Including the probability weightings, the *expected upside* is $297k and the *expected downside* is $50k (a ratio of 5.9 to 1). These expected values are obtained as the probability-weighed averages on the positive (upside) and on the negative (downside) parts of the distribution graph.

This project may be viewed as a wager of the expected upside against the worst possible loss, which is an expected $297k gain against $246 risked as total investments (a ratio of 1.2 to 1).

Results from this and the other scenarios are summarized and compared on Table 9.1 at the end of this section.

9.2. Two Pilots decision tree

The best possible outcome (HLV) is an $898k profit, the worst (LLV) is a $213k loss (a ratio of 4.2 to 1).

Figure 9.2: Income distribution, Two Pilots

Including the probability weightings, the expected upside is $333k and the expected downside is $60k (a ratio of 5.5 to 1).

This project may be viewed as a wager in which the expected upside is placed against the worst possible loss: $333k against $213k (a ratio of 1.6 to 1).

9.3. One Pilot decision tree

The best possible outcome (HLV) is a profit of US$949k, the worst possible (LLV) is a loss of $213k (a ratio of 4.5 to 1). As expected, the upper limit is larger than in the other two projects because the benefits are incurred one year earlier.

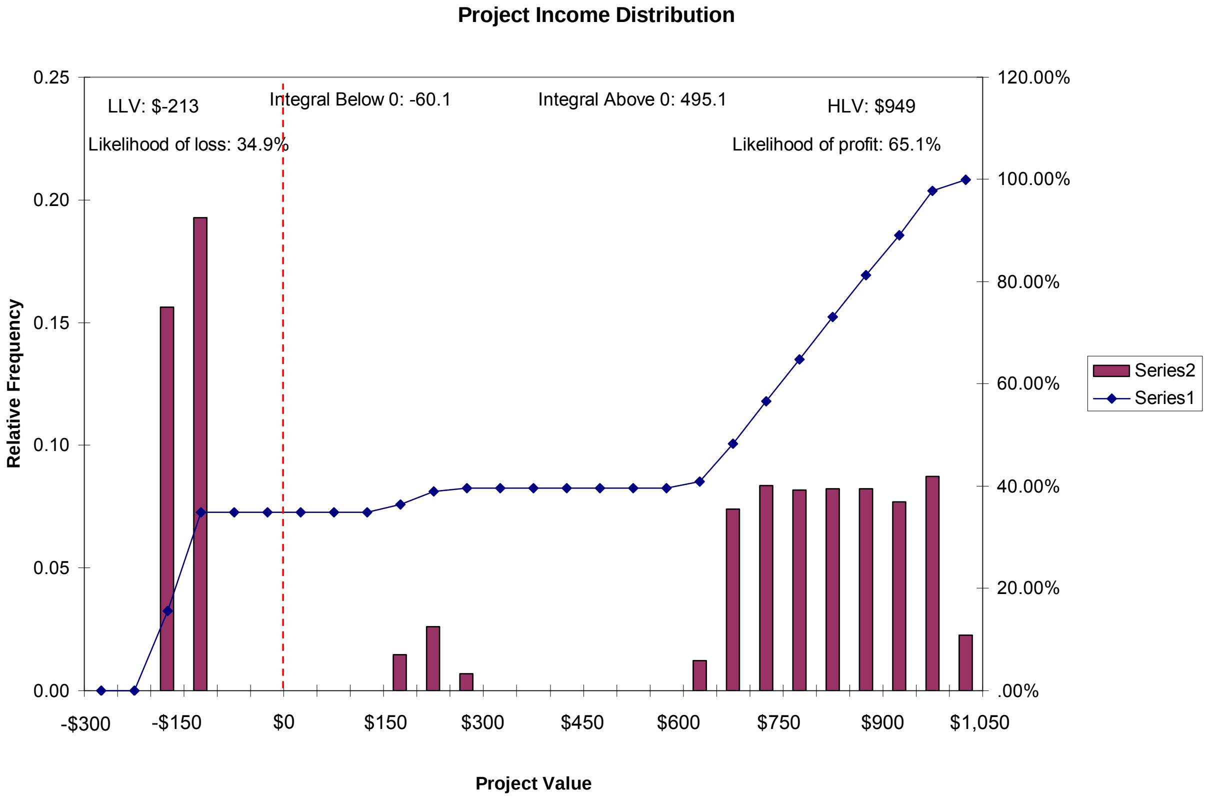

Figure 9.3: Income distribution, One Pilot

Including the probability weightings, the expected upside is $495k, and the expected downside is $60k (a ratio of 8.2 to 1).

This project may be viewed as a wager of the expected upside against the worst possible loss, which is an expected $495k gain against $213k risked as investments (a ratio of 2.3 to 1).

9.4. Comparisons

The *risk versus reward* character of the projects can now be compared against each other, so that a preferred path for RFID deployment can be chosen.

	Highest possible profit (*US$ thousands*)	Ratios		
		Highest profit / worst loss	Expected upside / expected downside	Expected upside / worst loss
1 Pilot	949	4.5	8.2	2.3
2 Pilots	898	4.2	5.5	1.6 [b]
3 Pilots	898	3.6	5.9 [a]	1.2
1 Pilot, 1 yr. delay	609	2.9	4.7	1.3

Table 9.1: Comparison between alternative deployment paths (projects)

One extra scenario has been added to Table 9.1 to illustrate sensitivity to time in this particular case of Embraer. A one-year delay in the One Pilot project will substantially affect its characteristics.

The ratio of the expected upside to the expected downside gives a measure of the *attractiveness* of the wager (or 'bet') one is placing, by comparing the probability-weighed average profit against the average loss.

The ratio of the expected upside to the worst loss is the best measure of overall project *risk*. It measures the average profit against the highest investment necessary, which may become the worst loss. The higher the ratio, the *safer* is the 'bet'.

Contrary to what intuition may suggest, running one single pilot provides not only the least risky of the alternatives, but also the highest possible profit and the most attractive wager. Provided, of course, that the company is confident that the pilot can be run within the first year, and that full deployment will follow in the second year (see Figure 8.6).

Delays in schedule will strongly affect the project due to the high discount rate practiced by the Brazilian company. In that case, it becomes a matter of choosing between:

(a) The attractiveness of the three Pilots project, with a ratio of upside to downside of 5.9, or

(b) The safety of the two Pilots project, with a ratio of expected upside to worst loss of 1.6.

The decision depends ultimately on how risk-prone or risk-averse the company is.

10. Conclusions

This report provides a comprehensive overview of the ROI analysis process, from the early stage of Value Drivers identification to the design and selection of a preferred RFID deployment project. The following conclusions are drawn from the work.

- There is still scarce quantitative work published to support ROI analyses for Automatic Identification technologies. The few contributions sourced by the authors came from academic papers published by Auto-ID Labs and other major institutions such as Stanford University.
- The IT and business consulting sector is a particularly disappointing source of quantitative work, although qualitative assessments are helpful in identifying Value Drivers.
- Benefits from auto-ID systems have to target multiple Value Drivers and be compounded across several types of aircraft parts, since the individual profit margins from any single part are low.
- Different companies are likely to prioritize their own particular set of Value Drivers, according to their core competencies, current market conditions and operational challenges.
- Pilots will continue to play a central role in the auto-ID adoption process. This is especially true in the aerospace industry, given its culture of safety and risk mitigation.
- Net Present Value calculations only provide a limited means of comparison between projects, and do not address confidence levels in success or failure.
- Decision trees can help build alternative paths for auto-ID deployment that may be counter-intuitive. In addressing risk, they provide a more comprehensive basis on which to compare different adoption projects.
- Levels of risk vs. reward can be tailored to match the end-user's investment profile.
- Decision trees bring the additional benefit of staged investments, and opportunities for management intervention and redirection as deployment unfolds.

11. Suggested Further Steps

Given the limitations in time and scope of the work conducted, the authors see value in expanding the research in the following ways.

- Broaden the research on quantitative methods of assessment for the remainder of value drivers in aerospace logistics.
- Work closely with a variety of end-users to build more robust benefit models.
- Seek to establish empirical data for the likelihood of success from one or more auto-ID trials, so that the confidence levels in the decision trees depend less on expert judgement and more on factual data.
- Conduct reality-checks of analyses against actual deployment projects that have already been implemented, to validate the usefulness of decision tree findings.
- In this particular analysis case, the discount rate employed in the calculations had a significant impact on results. It would be interesting to compare the sensitivity of other cases in which lower rates are practiced.

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