21st Century Technology
Retail Management Systems (RMS)

Functionality, Speed and Reliability: Greater operating efficiencies achieved rapidly throughout the retail enterprise and at considerably lower cost.

Real-time control ● Improved bottom line ● Loyal customers

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21st Century POS and RMS: Economical Functionality, Speed and Reliability

21st Century Point of Service (POS) and Retail Management Systems (RMS): Robust, High-Speed and Ultra Reliable with Economical, Broad-Based Functionality

Executive Summary

Overcoming common-sense, linear thinking when assessing technology requirements for 21st Century retail operations is a critical planning skill. Globalization takes on an entirely different meaning when enabling technologies and their growth in functionality are factored into the business model. Competition in all areas of the retail business endeavor will increase in volume and effectiveness faster than ever experienced in human history and the trend will accelerate far faster than most are anticipating. The competitive issue is not the rise of China, India, Vietnam, Korea, Brazil, etc.; it is "The Rise of the Rest"---*all* of the developing nations.

This document is the beginning of a series of papers addressing technology issues facing 21st Century Retailers. It is difficult to imagine a more competitive arena than the retail marketplace. It is also difficult for many to imagine the growth in the role technology will play in that competitive arena.

The role that low-cost, ubiquitous functionality, rapid deployment of new applications, low total cost of ownership and reliability will play in this competitive environment are treated generally throughout this paper.

Speed and Reliability are discussed conceptually throughout the paper with the justification that they are essential and poorly understood, especially the potential for unreliable technology (hardware and software) to seriously damage the bottom line performance of the 21st Century Retailer. The Point of Service (POS) and Retail Management Systems (RMS) software technologies arriving in the first two decades of the 21st Century will need to capitalize on the massive upgrades being brought forward (rapidly) in store systems and on the internet. Maintaining speed and reliability while growing the enterprise will be essential.

The essential role of fault tolerant POS software in achieving 21st Century performance and reliability is critical. In a bricks and mortar retail facility no other function touches every customer. No other function can collect the data, secure the transaction, and protect all parties like the POS. Early in the 21st Century, POS software will need to become faster, much more reliable, easier to use, and less expensive to own and support than prior-art (legacy) software systems. The good news is that 21st Century POS software, hardware and peripherals will be able to deliver on the promise---cost effectively.

Purpose and Background

The "need for speed": Both inherent system speed and speed-of-delivery (new applications) are focal points of this paper. Studies indicate that IT department backlogs continue to grow while Line of Business (LOB) executives and senior management need more services and systems capabilities faster and with lower cost (initially and long-term). This trend continues at the economic peril of the organization. 21st Century Retail Management Systems (RMS) technologies have valuable potential to reduce the performance gap in existing RMS systems and also to give the new retailer a running start at managing their new enterprise---profitably.

It is always fashionable to talk about change. However, few realize the extent and the speed with which changes are occurring in 21st Century technologies, especially in Computing

Technology and Information Management. There is one area that rapid change is certain and the speed with which it is coming is accelerating rapidly---and that is in Retail Management Systems (RMS) and the underlying technologies. While Gordon Moore's (of Intel fame) law gives some idea as to what is coming, it does not nearly indicate the pace with which computing speed, computing intelligence and data growth will impact how business will be transacted in this century. Early in the 21st century much of the processing and management of business data/information will be completely automatic and under the direct, and complete, control of NHL (non-human-like) computing intelligence. That means autonomous computer intelligence, and it is inevitable. Humans cannot process or manage the volume of data/information being generated today, certainly not in the time allowed for effective business decision making. It has been estimated that by 2010 the volume of global information will double every eleven (11) hours---every eleven hours! Nothing on the planet grows faster, biological or otherwise. Currently, a retailer's business information tends to double in about 1.2 years, but that growth rate is increasing rapidly. Interestingly, the size of the retail organization generally does not impact the growth rate. The small retailer must plan to deal with the information explosion, too. The good news is that the required technologies are evolving quickly to meet the challenge and at acceptable price levels.

In the 21st Century, new retailers, starting with a clean slate, require more functionality and performance than their predecessors did in their initial POS purchases (and at lower cost); and they require, as a given, the reliability and robustness historically associated with experienced sophisticated users' systems. Experienced retailers, with substantial investments in legacy systems, typically know a great deal about the strengths and weaknesses of their current systems environment. Their challenge is in moving forward fast enough to keep pace with 21st Century competition from around the globe who often will have new state-of-the-art hardware and software. It is possible with today's technologies to surpass, day one, much of the capability that experienced retailers have developed through years of effort. Witness the internet and ecommerce. While ecommerce is still a small piece of the retail market, it is growing rapidly, driven in part by new business models and powerful technologies connecting everyone---suppliers, retailers and customers around the world, 24x7. Internet speed and reliability will increase exponentially in the 21st Century. Those improvements increasingly will allow large retail organizations to consider the internet for applications they otherwise would avoid such as those made available via Software as a Service (SaaS).

To be and remain competitive, the 21st Century Retailer, whether a bricks and mortar enterprise, internet enterprise, or some combination of the two, will require 21st Century Technology-based systems to deliver the services to support customer-focused business strategies. The approach for 21st Century business strategies, as stated by the MIT Sloan School Delta Model, though not the focus of this paper, are:

- Innovative restructuring of customer relationships
- Segmenting customers for more creativity
- Delivering a value proposition that places the customer at the center of strategy.

In the MIT model, the customer is the center of attention throughout the planning and execution processes. To perform in the retail markets of this century utilizing a model such as promoted by MIT, *Retail Management Technologies will need to perform very large tasks quickly and dependably (reliably).* New applications will need to be placed on line much

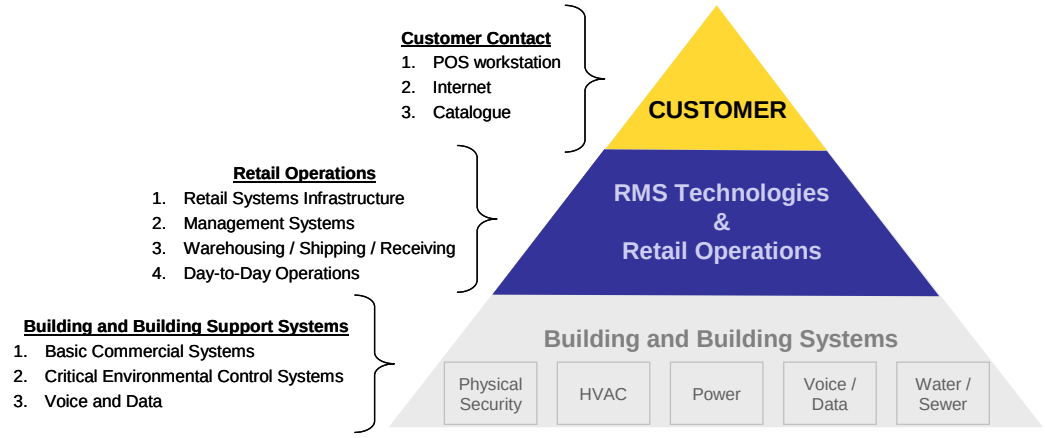

Figure 1. Simplified view of retail facility infrastructure

faster than the pace to date. In small retail businesses, the new applications will need to be available essentially instantaneously. Their competitive advantage will be in leading with new customer-focused capabilities.

The diagram in Figure 1 is a top-level view of a bricks-and-mortar retail operation. To achieve reliable operations throughout the retail operation requires robust systems all the way up the pyramid. While the proof will not be presented in this paper, a good rule of thumb is: To avoid compromising the reliability of the top layer, each lower layer must be about ten times more reliable than the one above it.

Applying the rule of thumb:

- Building Systems Level Reliability = 10 x Retail Operations Level
- Technologies and Operations Level Reliability = 10 x Customer Level

Not achieving these ratios puts each layer at risk of not delivering the technology performance purchased for that level. More importantly, the retailer-customer relationship and the bottom line are at risk.

The terms Reliability (Reliability Index), Availability, Robustness, Serviceability, Maintainability, Flexibility, Adaptability, etc., are used many times throughout the paper. Definitions for the terms, as used in this paper, are listed here.

Reliability: The *probability that some item will perform as intended for a specified period of time*; under a stated set of conditions. A variant of the definition that has more meaning is, *Reliability is the probability that a given function will be available to perform the desired function at a specific point in time under a specified set of conditions;* often within a 1-10 year window (see Confidence below).

Failure Rate (MTTF): The predicted rate at which a component, system or subsystem will fail under a specified set of conditions, usually stated as mean time to failure (MTTF), or mean time before failure (MTBF), or mean time between failures (MTBF). This paper uses MTTF.

Availability (A critical assessment): A *derivative of MTTF* and is expressed as a percentage of a specified period of time (typically one-to-ten years). Maintenance impact on the resulting availability projection is not included in these calculations and can become the main reason availability is compromised. Basic calculation: Availability (%) = MTTF/(MTTF+MTTR) X 100. This calculation does not include time required for maintenance.

Confidence (Certainty): The characteristic of an item expressed by *the probability that it will be operational at a randomly selected future instant in time* (often expressed as a percent chance).

Maintainability: The system can be maintained without affecting planned business operations. The actual time to perform maintenance activities, along with the associated risks should be well understood by the owner.

Serviceability: Scheduled service as well as service of failed systems can be performed quickly and fall within the projected mean (average) time to repair (MTTR).

Flexibility/Adaptability: The ability to quickly and economically adapt existing hardware, software and systems to meet new demands without degrading reliability, maintainability and serviceability. This usually requires good change control procedures.

As one might expect these terms are interdependent. However, remaining focused on reliability and availability help align the other requirements.

This paper focuses on the top of the pyramid, especially the Point of Service (POS) portion. That focus is driven by two simple facts:

1. Transactions at the POS workstation consummate the customer's experience.
2. Those transaction records drive every aspect of retail operations and requirements down the pyramid.

A complete treatment of the pyramid in Figure 1 is far outside the scope of this paper. That does not imply that every layer is not critical to the business mission. It simply means each layer is complex and deserves its own detailed assessment. Somewhere in the retailer's organization a document should exist that treats the pyramid requirements top to bottom. The ability of each layer to dependably support the layer(s) above it is critical to the overall customer experience. This becomes increasingly important as ecommerce (i.e., the internet) grows and allows business to be transacted at "the speed of thought", 24x7, around the globe.

In this 21st Century very high speed environment, just how much inconvenience will (can) the customer, senior management, line-of-business (LOB) executives and staff tolerate? Be careful when you see or hear numbers stating the availability of systems or services. The "availability" percentages stated, often loosely, by purveyors of technology and services translate as follows:

Availability (%)	Time Lost/Year
99.0	87.6 Hours
99.9	8.76 Hours
99.99	53 Minutes
99.999	5.3 Minutes
99.9999	32 Seconds

99.99999.....3.2 Seconds

99.999999.....0.32 Seconds

99.9999999 .....32 milliseconds

There is a large range of issues around the 'Time Lost' figures depending upon what part of the RMS is being discussed. For the moment, let us stay focused on the customer.

Here is an example of the importance of speed and continuity of business transactions: Early in 2008, IBM performed a demonstration using two Cisco Nexus 7000 switches, each able to handle 15 Terabits (10^{12}) of data per second. They pulled the plug on one of the switches and the other picked up the workload with only a 16.6 millionths of a second loss in data; yielding essentially real time failover and continuous operation for the customer. This technology is being implemented around the globe at a blistering pace. Speed, reliability and availability of the internet increase exponentially. Additionally, the switch has the ability to manage server and storage resources across an entire internet data center across multiple platforms---reliably. It changes everything.

Bricks and mortar retailer: How long will the customer tolerate the POS workstation being out of service while standing in line---without becoming upset? 5 Minutes? 10 Minutes? That means the POS function must available 99.999% of the planned time to keep the customer happy.

Internet Retailer: How long will the customer wait on a response to a query or to enter an order? 3 seconds? 10 seconds? 20 seconds? That means the online services must be available 99.99999% (not including internet performance issues) of the time, 24x7 to attract and keep a customer online.

Not achieving these levels of availability is certainly a choice to be made based on individual business needs. It is important to realize though, that there are retailers performing at the top levels allowed by available technologies *now*.

While this paper addresses the role of POS and RMS systems performance and the required reliability to meet operations objectives in some detail, it is by no means all inclusive of the topics presented. The reader is encouraged to seek the resources available from the many credible RMS hardware, software, systems and consulting-services suppliers in the market place.

RMS technologies may not be considered by many owners and users to be the tools of competitive advantage they once were, but they are more indispensable than ever in ways that are often not perceived. Legacy systems in particular will need considerable investment to transition to the new 21st Century retail market reality.

Good News, Bad News: First the good news, it is technically feasible and cost effective to climb up on the 21st Century Technology curve and to stay there. Now the bad news: The business risks of not doing so are numerous and potentially quite damaging to the bottom line.

Aging Systems vs. 21st Century POS/RMS Technologies

It will need to be fast and feel good to the customer *every time*.

It is well documented that most legacy systems cannot deliver new applications on time and on budget, certainly not economically; and they often contain "time bombs" that can seriously disrupt operations. Importantly, RMS owners and end-users who lag too far behind the technology curve will be penalized substantially by the market place and by total-cost-of-ownership (TCO) issues. The negative impact of systems aging on lagging performance, reduced reliability of RMS operations and TCO (maintenance/service in particular) are addressed throughout this paper. The negative impact of age-imposed degraded systems performance on financial results and customer satisfaction will be substantial. The customer is going to migrate to the retailer that can best meet their needs, quickly, most cost

effectively, and to the retailer that makes the overall relationship feel good. Unquestionably, that is a one-customer-at-a-time focus and service level. It will need to be fast and feel good to the customer *every time*.

"We live in the age of the unsatisfiable customer".

It has been said, probably by a business person, that "we live in the age of the unsatisfiable customer". Not performing to their expectations can make that a painful fact.

The chart in Figure 2 illustrates the intimate relationships/links among all the players in the retail value chain. Whether the retail establishment is small and has few of the functions shown, or a large sophisticated retailer, the concept is the same---every player (internal and external) is increasingly wired to the value chain.

Additional goals of this paper are to communicate fundamental connections among key RMS functions and the overall value chain from supplier, to retailer, to customer---the chain managed by today's retailers. Regardless of who manufactured or supplied the product or service purchased, the sales receipt has the retailer's name on it. In the *customer's mind*, the retailer owns any problem with the product or service, regardless of any stated policies. That may not be fair, but it is a fact.

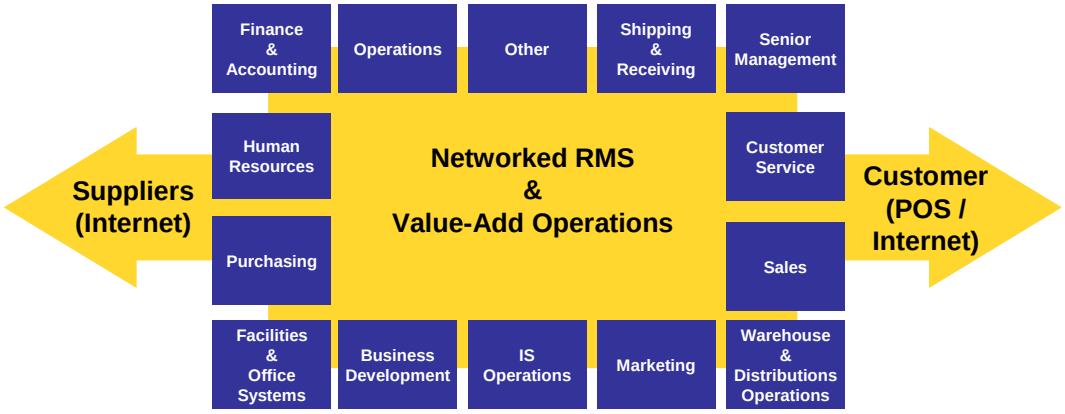

Figure 2. The end-to-end value chain---Driven by the POS or Internet Transaction

Low-cost, ubiquitous functionality. POS and RMS buyers often say, "I don't need all those bells and whistles". It is important to separate the "bells and whistles" concern from unforeseen functionality requirements. Credible POS and RMS suppliers are very experienced in their trade. Most functions included in base systems are valuable, especially in the long term. If they are not useful to the individual retailer, they can be ignored at *very low* TCO impact. The best of all worlds is to be able to purchase, at an acceptable price, the initial POS or RMS hardware and software that has extensive functionality, high sustainable speed, superior reliability, and the ability to adapt to new requirements quickly, reliably and economically. This protects against problems of growth where new functionality is required; and the POS or RMS is not capable without substantial modification, and assures that the initial purchase is kept to a small percentage of the TCO. Maintaining speed and reliability as the business grows and matures are both key operational requirements.

Superior financial performance and operating excellence will become increasingly dependent on RMS technology. A repetitive message in this paper is the critical importance of sustainable speed and reliability (both generally need to grow as the organization grows) throughout the life of the POS and RMS supporting retail operations.

4 key steps

Lessons learned from legacy systems --- a 4-step assessment: What is good and what needs to go away? This paper overviews the key elements of achieving required 21st Century POS and RMS performance, economically and reliably, utilizing a few essential

guidelines. A key step for experienced retailers, especially those with substantial investments in legacy systems, is to perform the following four-step evaluation:

1. Where are we?
    a. What is working? What do we like and *need* to keep?
    b. What is not working and *must* go away?
2. Where do we *need* to be (new capabilities)?
3. What is the *difference* between 'where we are' and 'where we want/need to be'?
4. What is *causing* the difference?

"Facts", as John Adams once said, "are stubborn things".

As simple as the process appears to be, it is generally not performed in a structured way up and down the organization. Done well, it is extremely valuable to achieving competitive customer service levels and excellent financial results. Dealing with the simple four-step process factually and honestly is invaluable. "Facts", as John Adams once said, "are stubborn things".

Many topics and concepts presented in this paper can become quite technical and complex, especially for new owners/users and many references may not be included in this paper. If further information is required, please visit the GoldTech, Inc. website: *www.goldtechservices.com*

POS and RMS Models for This Paper

21st Century POS and RMS can take many forms. System requirements are governed by business needs for a broad array of retail businesses spanning an extreme range of size, needs and operational complexity. This paper outlines basic systems characteristics that apply to each level of size and complexity that will assist the retail owner and end user in designing, procuring and implementing required RMS technology and services to meet expressed or implied commitments made to their customers. The focus throughout this document is on the *retail customer*. It may be reasonably assumed the required technologies and skills are economically available to design, procure and implement systems that meet the operating and financial needs of the 21st Century Retailer.

Systems models addressed in this paper include:

- Single Register POS
- Basic Single Store w/Server
- Single Store (Customers and Suppliers)
- Multiple Registers
- Multiple Stores (HQ, Customers, Suppliers)
- Networked Systems
- Multiple Stores WAN
- Internet
- Software as a Service (SaaS)

Each of these areas will be addressed to some degree, but the primary focus will be on the front end of the systems---*the POS software and hardware*.

End-to-End Performance and Reliability

It is much more cost effective to keep customers than to find new ones.

End-to-end performance and reliability can mean many different things to owners and end users but, whatever it means to each, it requires reliability that often exceeds legacy systems capabilities. The financial and customer-relations penalties increase as the gap between legacy systems capabilities and available 21st Century RMS Technology is allowed to widen, and this penalty will be amplified by the growth of global competition from newcomers with state-of-the-art technologies. However, surveys indicate systems technology and high-reliability remain low on the list of priorities and budgets. For reasons discussed in this paper, speed, reliability and availability are critical to meeting financial performance objectives and are essential to customer satisfaction and retention. *It is much more cost effective to keep customers than to find new ones*.

Functionality, operating speed, speed of new application delivery, and reliability requirements must be established and grown with confidence throughout the planned life of the RMS. As functionality and speed increase, reliability becomes substantially more critical. Any Formula 1 or NASCAR driver will probably agree that, a collision at 10 MPH is an agitating inconvenience from which recovery is usually simple; a collision at 170MPH is life threatening, extremely expensive and immediate recovery is usually out of the question. Speed is pursued because the time allowed to complete a task (such as winning a race) is shrinking. It makes no logical sense to think there is time to recover from a crash if there was hardly enough time to perform the task correctly the first time. What is the penalty when the pit crew is *just a little slow* changing the tires out or refueling? No matter how good the driver, she loses.

Reliability must be maintained in order to meet customer-centered operating requirements. Accordingly, careful definition of the reliability/availability needs for the POS and/or the RMS to meet mission requirements becomes a critical step in the planning process. Fortunately, today required availability and reliability levels are achievable with modest levels of investment.

Broad-Based Functionality and Hi-Flex Adaptability

The role of 21st Century software: Economical, high-performance, easy to install POS systems with broad, tightly-integrated capabilities to meet future (often unforeseen needs) of the retailer are essential to the rapid deployment of new operational capabilities while retaining required levels of systems integrity and reliability. Low-cost "throwaway functionality" in the software is essential to affordable POS technology that can grow with newly identified needs of the owner with no modification or upgrade. Verifiable, broad-based inherent ("standard") functions that are easily adapted to the new needs while maintaining speed and reliability are essential characteristics of the 21st Century POS.

To take full advantage of POS hardware advances, 21st Century software must have a low first cost, be easy to install, be easy to learn (for owners and operators), require low maintenance and require only infrequent upgrades. True 21st Century software will be built on clean platforms that capitalize on the reliability of 21st Century hardware and retailers' "lessons learned" without the burden of legacy system shortcomings that are a liability to customer relations and retailer profitability.

For the experienced retailer with substantial POS and RMS investments in place, the needs are somewhat different. 21st Century Retail Technologies, both hardware and software, will either replace the existing systems or be integrated into the existing environment without compromising the required speed and reliability of the new/enhanced systems; a much more difficult task, yet not optional. Legacy systems will be under enormous pressure to meet management demands due to advances in retail-specific systems and the enormous growth in internet speed, functionality, and reliability, thus putting powerful tools in the hands of new or more aggressive competitors who are saddled with legacy systems. The rise of the

developing economies around the globe will bring a whole new meaning to retail in the next two decades.

Functionality: More, Faster and For Less

Initial purchases of POS systems, whether for single-establishment firms or for medium and large retailers, must have a large repertoire of inherent capabilities at price levels that initially allow economical, minimal use of total POS capability. Custom SW development (contracted or in-house) and frequent SW and HW upgrades to achieve the next line of business or management functional requirements, increases maintenance costs and reduces reliability, especially in the long term.

As time progresses, entry level users will need to increase store sales, store sales visibility, better manage customer relations, use more sophisticated pricing and inventory control methods, increase financial and accounting visibility, add stores, use more intimate connections to suppliers, etc. quickly and easily. When these requirements can be met without, or with only minimal, modification of the original SW and HW systems, the more stable and reliable the overall system will be.

As the organization grows and systems mature, maintenance costs become an increasingly larger budget burden for all levels of the RMS. As experienced users know, minimizing custom SW development and standardizing HW improve reliability and reduce time to market with new capabilities. Initial HW and SW functionality, speed, reliability and straight-forward adaptability greatly influence long term maintenance costs.

One simple idea to keep in mind: No matter how reliable the current systems are, that reliability decays inexorably with time. Competitive pressures from new entrants around the globe, most of them utilizing state-of-the-art technology, will further press the need for staying current in RMS capabilities.

Speed of Delivery and Software as a Service (SaaS): The concept of paying only for the required RMS functions, rapid deployment of needed services, lower initial capital investment, lower TCO, etc. are powerful drivers in Software as a Service (SaaS) gaining interest and credibility at all retail tiers. The flexibility to add new functionality one function at a time can be a substantial TCO savings in the long term. Because of the many advantages of SaaS, it is anticipated that the technology will, in a very short time, become a preferred way for entry level technology buyers to economically procure needed functionality and reliability quickly and easily. More experienced users, encumbered with legacy systems, practices and associated reliability and security concerns, will be slower to adopt. They, however, will increasingly find the SaaS solutions attractive in order to improve delivery time for new applications in a customer-centric environment. More on SaaS below.

Hi-Flex Adaptability

Adapting to customer needs quickly and reliably requires basic POS and RMS that have inherent, *sustainable speed and reliability in both hardware and software.*

“Seamless performance” is achieved through durable, robust, well-conceived and implemented “seams” between systems components, subsystems, extended systems, departments and organizations, whether these elements are within a single enclosure, building or spread across the globe. Seams between the customer and retailer, between retailer and their suppliers, among internal operating departments or lines of business (LOB), must be such that they maintain reliable, robust continuity of services at all levels of the organization 24x7. Unplanned downtime (unplanned loss of systems to handle business transactions) is becoming a major business liability to all retailers, large and small. Planned downtime for maintenance is also becoming more difficult to manage and *maintenance is risky*. Unintended consequences of planned maintenance actions and errors can cause costly

systems failures and make recovery and restart difficult at best. Unplanned downtime associated with maintenance errors are well documented in the IT community.

Nothing, *absolutely nothing,* of any consequence happens without fully functional, available RMS technology.

The 21st Century customer is intolerant of even minor inconveniences (2-3 instances and they are gone). RMS are the logical and physical links in supplier/retailer/customer relationships and are the key to competitiveness and profitability. Nothing, *absolutely nothing*, of much consequence can happen in a modern retail operation, large or small, without fully functional and available RMS technology.

Entry level systems: No, or minimal, requirements for custom SW development and no, or minimal, requirements for HW changes result in more rapid deployment of new capabilities at minimum total cost of ownership (TCO). For the medium and large scale retailer, overall systems design is much more complex and must not be encumbered by poorly performing POS technology. The POS contribution to bottom line performance is multifaceted. First and foremost, it is the final link in the customer buying experience. Second, the information accumulated and distributed from the register function drives the entire retail enterprise. This reality requires great care in the selection and implementation of the POS function.

SaaS Solutions

Software as a Service (SaaS) serves functionality, speed of delivery, and reliability well and at reduced costs, both initially and long term. The potential advantages of SaaS solutions are:

- Rapid deployment of initial and new applications/services.
- High reliability/Availability: This is heavily dependent upon the reliability/availability of the internet, as well as the technology and facilities infrastructures of the supplier. A carefully constructed service level agreement (SLA) is required.
- Pay only for resources used.
- Backup of critical data and documents (Verify backup and disaster recovery procedures of the supplier.)
- Security (physical and data) for supplier systems and facilities.
- Web hosting services.
- Maintenance and upgrades performed by supplier. Again, develop an advantageous agreement.
- Low initial cost and verifiable TCO.
- Improved budgetary control.

To repeat, acceptance of SaaS is growing rapidly in the retail community and is beginning to make inroads into the strategic thinking of larger players. SaaS acceptance barriers for larger retailers tend to gather around: 1) Not a proven technology, 2) Security issues, 3) Long-term stability of the SaaS provider, 4) Responsiveness, 5) Reliability/availability, 6) Disaster recovery and backup. Potential speed-of-delivery for new applications and TCO benefits seem to be accepted by the retail market. SaaS will be addressed briefly in the "Reliability and Availability Concepts" section. Current activity by the major internet players (Cisco, Dell, IBM, HP, etc.) is moving the internet to the next level. Speed, security and reliability will improve quickly by orders of magnitude resulting in performance attractive to even very large players.

Reliability and Availability Concepts

In the customer-centric 21st Century, high performance retail management systems are essential to process business transactions, track and report business activity and help

manage: Internal resources, the relationship between the retailer and their suppliers and between the retailer and their customers, placing the retailer in the difficult position of having to manage all of it.

From a practical perspective the only real relationship in the process that is of practical value to the customer is with the retailer. That reality means the retailer receives both the accolades for performance and the blame for the lack thereof. Few activities of staff members in any retail operation affect the customer like those last few minutes at checkout; and *every customer will experience that last step at the register* unless they are on the internet or using catalogue sales.

Operational dependency on RMS is *total and critical.*

That said, dependence of the retail store or organization on the planned availability of the POS terminal and/or back office systems to process and report business transactions is *total and ultra critical.* Effort expended within the retail business without the direct support of the POS and RMS is either not possible or of low value.

Poor systems reliability and reduced availability jeopardize the business, alienate customers and inconvenience suppliers, especially those working in a just-in-time (JIT) environment. Some basic principles of achieving required levels of RMS reliability and availability are addressed here. For medium and large scale users, the required detailed analyses are much more complex. The principals, however, remain the same.

Reliability and Availability Models

The Reliability/Availability of RMS is a substantial topic. This section is intended as an introduction. The underlying calculations to support stated performance levels will be eliminated for simplicity. Documents to assist those who wish to further pursue the discussion in detail are available from various sources. See the appendix for assistance.

POS Single Workstation

An example single POS workstation is illustrated in Figure 3. Many applications will not require all the peripherals. The calculation results shown for figure 1 utilize only the integrated POS with touch screen and mag stripe reader. Adding other peripherals to the base system rapidly reduces overall reliability and increases system failure rates substantially as the following discussion shows. Reduced reliability as hardware is added does not mean the system reliability is not adequate, it simply means it must be considered carefully in the initial system selection and watched carefully as the system ages and grows.

The text in Figure 3 describes the system components and operating period for the reliability results displayed. The first example is for hardware only.

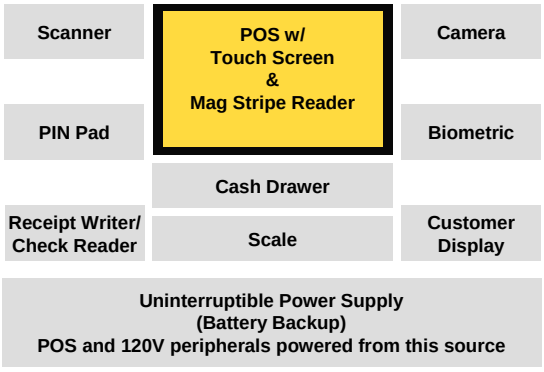

Figure 3. Single workstation

Assume for the example in this figure that only the integrated POS with touch screen and magnetic stripe reader has a failure rate of once every 5 years or so, and that all functions must be available at all times.

Reliability Index:

1st yr = 83.9%

2nd yr = 70.4%

3rd yr = 59.1%

4th yr = 49.6%

5th yr = 41.6%

The average failure rate of once every 5 years means there is a 58 percent chance of the system *not* being available when needed in year 5. Actual reliability will typically be much, much lower.

Now add a new peripheral: The cash drawer is added, assuming for this example the same failure rate as used for the previous POS workstation calculations. Further assume the new combination is required for all transactions. The system reliability then becomes:

1st yr = 41.05% (Stated another way, there is a 59% chance the system is not available when needed in the first year)

2nd yr = 35.2%

3rd yr = 30%

4th yr = 24.8%

5th yr = 20.8% (an 80% chance the system will not be available when needed)

NOTE: No POS software is included in this model.

Two general observations to be made from the example:

1. The reliability of a single system decays quickly with time (age-imposed mortality).
2. The reliability is reduced (rapidly) as new essential peripherals are added.

An important question to ask at this time is, how long will the system be out of service for a given failure? Always try to determine the worst case for total time to repair, test and return to service. The reason the question is important is that the POS terminal (system including SW) will potentially fail quite often (regardless of vendor). Depending on the nature of the failure, it may require from a few minutes to days in order to repair and return the system to service. *A single POS terminal is probably not adequate to assure POS terminal availability for most retail operations*. See discussion below.

The next obvious question: Can business operations tolerate the time required to repair and return to service?

There are ways to help with this systems problem. One is to purchase very high reliability components. That helps, but not as much as one might expect. For example: Doubling the time before failure to 10 years, the new reliability figures for the example in Figure 3 become:

1st yr = 91.6%

2nd yr = 83.4%

3rd yr = 76.8%

4th yr = 70.4%

5th yr = 60.4%

Improved, but only if such products and peripherals are available. Still, if a failure occurs, the time to repair, test and return to service is an issue and may be at least as long as for the previous system.

Note: If all essential systems components, including software, are included in the reliability calculations, the overall reliability would be much, much lower than the example. *Much lower!*

Obtaining the required POS availability: An alternative approach that offers not only improved reliability, but utilizes the same POS system and peripherals outlined in Figure 3 is shown in Figure 4. And, the problem of time to maintain, repair and return to service is eliminated*, the POS function becomes continuously available.*

Importance of POS Software Fault Tolerance: First it necessary to understand what is meant by the expression *POS software fault tolerance* in this paper.

> **Definition:** *POS software will operate normally with the loss of availability of store systems such as failed server(s) hardware, loss of communication (e.g., broken cable), server software failure, etc. Upon repair and return to service of failed systems, the POS software will seamlessly connect and update store records in a local server or remote systems---no manual*

intervention required. Following a power interruption, the POS workstation shall restart normally and synchronize seamlessly with store systems.

To achieve POS software fault tolerance as defined here, suppliers will need to aggressively take advantage of the following histories and current trends:

1. Knowledge of lessons learned from the well documented history of POS shortcomings (legacy systems issues) that have hindered retailers over the last two-to-three decades.
2. Hardware reliability, speed and functionality continue to grow at an exponential rate and all at *substantially lower cost*.
3. Serious upgrades of the internet in speed, reliability and functionality by the major providers of hardware, software applications, systems, communications and facilities.
4. Improvements in POS peripheral technology and new functionality
5. Advanced security technologies

21st Century POS Software Fault Tolerance, combined with the elimination of issues associated with legacy systems, undoubtedly is one area with significant potential to improve customer relations and bottom line performance for all retailers across the industry.

Multiple POS Registers

Multiple POS registers offer a number of key advantages over the single workstation solution, even for small retailers who don't see the need for two registers. The example in Figure 4 illustrates some key points.

Continuous Availability

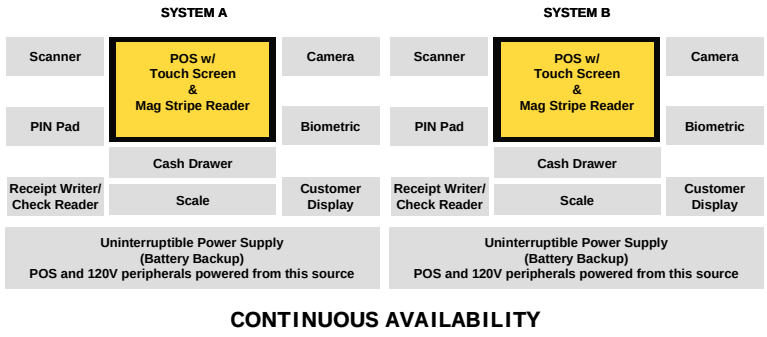

Figure 4. Systems A and B are duplicates of Figure 3

While both System A and B may be in service simultaneously, either can carry the workload if one fails. The reliability index figures for this approach with the failure rate of one failure in approximately 5 years for either A or B:

1st = 99.3%

2nd = 97.4

3rd = 94.7

4th = 91.2

5th = 87.4

NOTE: A fully configured system with POS SW will be only a fraction as reliable as the example.

Interpreting what has changed versus the single register in Figure 3:

In year one the dual system in Figure 4 is at least 10 times more reliable than the single system shown in Figure 3. There is only a 0.7 percent chance the system will not be available when required year one.

In Figure 4 systems are 200 times more reliable in year 5 than the system in Figure 3. Importantly, this configuration extends reliability and availability throughout the useful life of the system.

Remember: Examples thus far are still for hardware only.

Other important factors:

- The dual system in Figure 4 is 100 percent serviceable and maintainable without any interruption in workload.

- The increase in the number of system components results in more component failures for the given mission period. This affects service frequency but the system function is maintained.
- Service, maintenance, upgrades and testing can be performed on each half of the system while the other remains in service---minimizing risks associated with maintenance activity, upgrade changes and inconveniencing the customer. The approach achieves a practical 100 percent system availability.
- The features listed as major attributes of the dual system are enhanced by fault tolerant POS software

The first cost of the dual system is higher than a single system, but the operating advantages are generally well worth the investment for most users. Medium and large users will often have multiple POS registers in each store as a general operating requirement; so with care, the advantages outlined above are achieved without added costs.

One last chart of fundamentals before proceeding. Figure 5 depicts what is often referred to as the "bath tub effect". Stated simply, it outlines three important areas for the owner to keep in mind for the purchase, implementation and long-term operation of their POS and/or RMS. Three observations to keep in mind:

1. The specified mean time to failure (MTTF), or average failure rate, applies only between the periods indicated as Infant Mortality and Age Imposed Mortality on the chart.
2. Infant mortality time is usually short (days/weeks), and failures in that period are usually associated with quality of components or workmanship. The retailer should consider the effect of surprise, short-term failures on planned operations, especially during business startup operations. Again, the negative impact of these failures is minimized or eliminated by using appropriate dual or multiple registers.

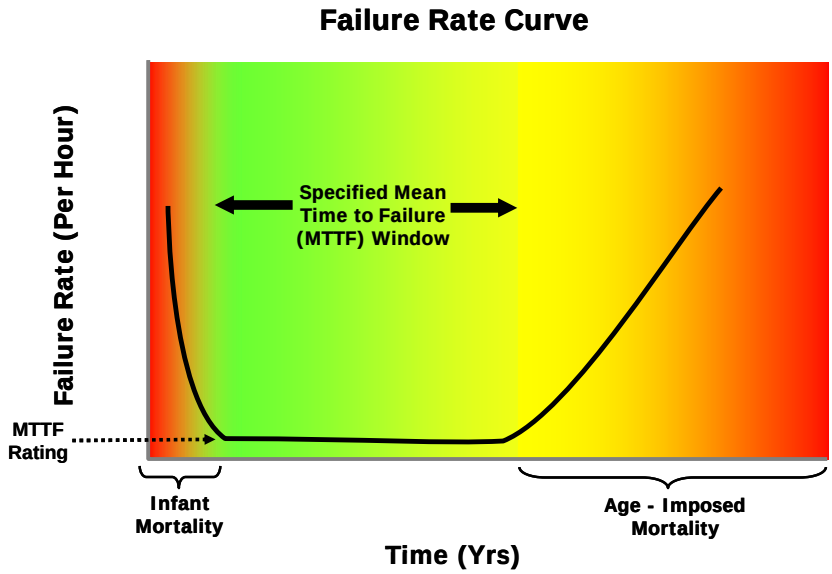

Figure 5. Effects of New and Old

3. Age-imposed failures occur simply because of the age of components or subsystems. Business risks and budgetary considerations are best served for systems in this category by having a long-term, retirement plan based on trusted suppliers' best estimates versus the retailer's needs and uses.

The chart is a simple reminder that age is a limiting factor in the useful life of technology-based systems. The IRS allows accelerated technology write-offs for a reason.

Inside the POS workstation

The diagram in Figure 6 shows a single-board computer with POS software (SW) in a single enclosure configured as described in Figure 3 above. As the notes in the figure describe, the

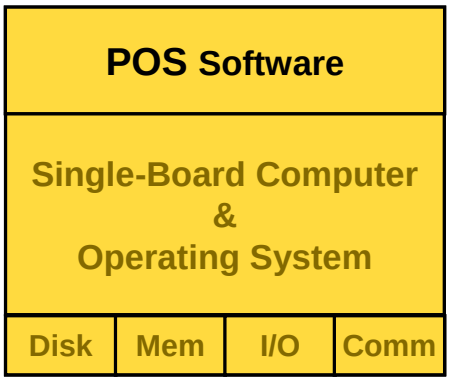

Figure 6 Single Computer and POS Software

Assume that the average failure rate of the computer function, with disk, memory, input/output and communications is once in about 5 years. The overall reliability is then the same as Figure 3. However, now assume POS software is added with a similar assumed failure rate of once in 5 years. This simplifies the example. In reality SW is much less reliable. The system reliability then becomes:

1st yr = 42%

2nd yr = 35%

3rd yr = 30%

4th yr = 25%

5th yr = 21%

Actual experience will yield much lower reliability than shown in the example. Software is notoriously less reliable than hardware.

overall reliability of the combination is affected substantially by the reliability of the software. In practice, software (applications, operating system, I/O interfaces, etc.) is unquestionably the lowest reliability component in the system, and overall POS reliability will be much lower than indicated in the example. It is critical that the OS and POS software perform reliably in order to keep the overall system reliability acceptable to the retailer. Hardware, in general is reasonably reliable and that reliability will improve rapidly and steadily as speed and functionality continue to increase for digital systems.

Computing/digital technology continues to be one of the very few real bargains across the entire commercial spectrum. As a reminder, the assumed values used in the calculations are for illustration purposes. *The failure rates for available hardware and software (especially software) components may be significantly higher, thus lowering substantially the overall reliability of any given configuration.*

As the reliability data for Figure 6 indicate, the overall reliability of the basic Computer + POS software combination is significantly lower than either of the two components. The idea here applies throughout the Retail Management Systems: As the required building blocks (scanners, displays, printers, other software, servers, networks, etc.) are added to complete a functional system and to grow the organization, *the overall reliability of the retailer's complete system decreases rapidly unless the component failures are compensated by overall system design.* For the small retailer, the analysis is relatively simple; for the medium and large retailers the analysis is considerably more complex.

21st Century POS Software Design brings real fault tolerance and improved reliability.

The difficulty of restarting (manual interventions required) a POS workstation (or workstations) following loss of power, lost communications to store systems, server failures, etc., must go away. The impact on financial performance, as well as the risk to dependable business intelligence, is too great to continue current/past practices. Large retailers have learned how to circumnavigate existing software issues, but the legacy systems they own will have difficulty keeping pace with new technology. Overcoming issues of non availability of POS workstations due to poorly designed interfaces to store systems is critical. Because of the hardware and software complexity of modern retail management systems, every effort must be made to take full advantage of the hardware

technological advances (and accompanying cost reductions) to reduce the problems associated with prior-art software. The good news is it is being done.

The POS workstation fulfills many critical functions relating to every transaction in a store. Every action throughout the enterprise (one store or thousands) is dependent on reliable, highly fault tolerant performance, day in and day out, of their POS and RMS.

If the POS is powered up, it must be able to handle transactions.

Conceptually, the POS software and workstation must work reliably independently of store systems. If the POS is powered up, it must be able to handle transactions, AND must recover seamlessly (non-intrusively) when building power, communications, or stores systems are restored. Goal: No negative impact on the clerk or the customer---*never negatively impact the customer standing in line.*

Checkpoint

Figures 3, 4, and 6 are diagrams of basic POS systems without the details of each component considered. The failure rates assumed are for illustration purposes only. Failure rates for available computing hardware, peripherals, software, etc. may be considerably different and may vary widely from supplier to supplier. The failure rate for each system component, as well as the overall system, should be known to the buyer---as a minimum, they affect the warranty and the maintenance/service contract. The mission requirements (retailer's expectations) may not be met. *Worst case, the customer is inconvenienced, maybe accompanied by an extreme reaction like leaving---permanently*.

Unfortunately, reliability data are often not available from POS and RMS suppliers, or the data are not determined in a rigorous enough manner to make the data trustworthy. Reliability may be calculated from mathematical modeling or from field failure rates. Due diligence is required for both methods in order to achieve useful (verifiable) results. With some effort, a good first approximation of the probable reliability and availability of a given POS or RMS configuration can be determined.

General observations to this point

From a reliability perspective, basic POS systems, including POS software, computer and OS, and peripherals are conceptually in a series-connected chain where the failure of any one component will disable the system; resulting in a low reliability index, especially if high failure rate components are used.

The available basic POS hardware functions as shown in Figure 3 have acceptable failure rates when properly applied and are available from many reputable sources. For reasons stated earlier, where a register must be available at all times, more than one register will be required.

Peripherals such as scales, scanners, cameras, printers, displays, etc. very widely in quality and reliability. Again, there are a number of top-quality suppliers for each item.

The dependable operation of the overall system is also significantly affected by the quality of implementation whether it is the assembly and start up of the basic workstation or the interconnection of components/peripherals and networks to create more complex systems.

Maintaining store systems operation throughout widely varying conditions and component failures is a systems design problem. *The POS workstation (especially the software) is a key element*. Proceed with the diligence due.

Networked Systems

Networked systems encompass a broad array of possibilities for configuration and needed performance. Functionality, flexibility/adaptability, speed, security and reliability again are

elements to evaluate carefully and early when establishing the RMS technology requirements. Long range planning is critical to constraining TCO and meeting performance requirements.

Single Store Internet Example

Again, beginning with the POS and required functions, the system may look something like that shown in Figure 7. All the elements in Figure 7 are essentially available off the shelf,

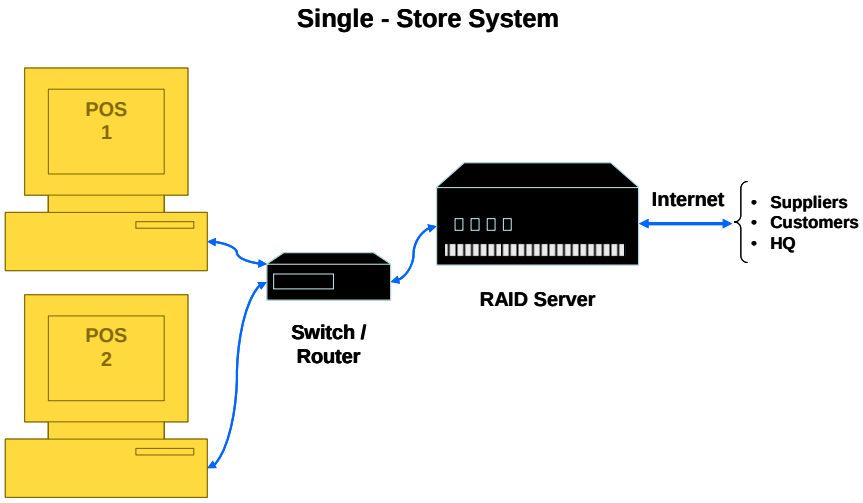

Figure 7. A simple store network connected to the entire value chain

including software. The example in the figure includes two registers to increase the reliability and maintainability of the POS function to levels that equal or exceed the other elements of the system. If the system is to support both in-store and internet sales, care must be taken to assure acceptable performance at each level. Speed and reliability are both critical, especially of the internet communications link. The basic concept shown can be implemented with modest investment.

Multiple Store Example (Internet)

The store system depicted in Figure 8 may be implemented via a private wide area network or a virtual private network (VPN) over the internet. Increasingly, the internet is the method

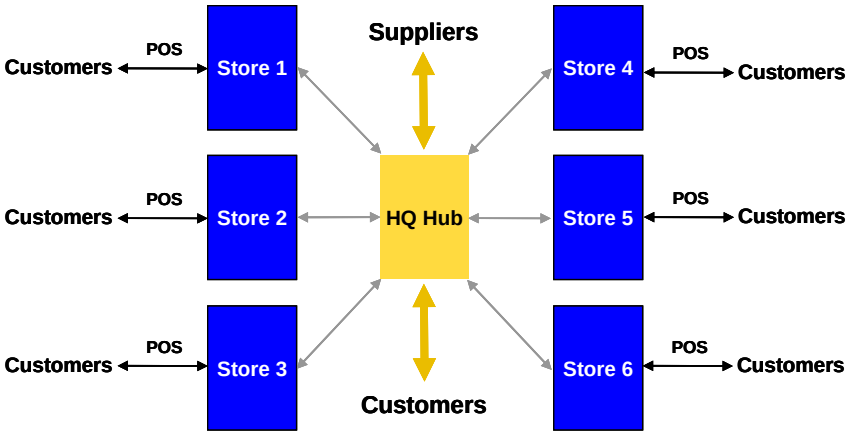

Figure 8 Centralized operations

of choice. Improved speed, reliability, flexibility, adaptability, security, and reduced costs make the internet option attractive. As the volume of business increases and more transactions are completed via the internet, there will be increased pressure on end-to-end speed and reliability. For larger retail operations, multiple (redundant) communications paths are often required.

If POS workstations located in each store are able to maintain adequate operating speed and maintain reliable store operations, the multi-register, multi-store requirement may be met with greater flexibility and speed of implementation. Reliability is always well served by inherent, stable speed throughout the system.

Private Wide Area Network (WAN)

Much of what is shown in Figure 8 above may be implemented with a private wide area network (WAN) approach. The private WAN approach may offer advantages, especially where security issues are such that exposure to the internet is not acceptable. Private WAN solutions are not a focus of this paper.

The Impact of the Building Environment

The overall quality of the base building and the building systems significantly affect the reliability of all technology layers shown in Figure 1. Building integrity, basic systems and security are often not evaluated to the extent necessary to assure adequacy to support the technology layers and the overall mission. To be certain that a building can meet the business requirements, there are a broad range of issues that should be evaluated and documented:

1. Support planned growth
2. Structurally adequate for the climate and weather experienced for the area
3. Air conditions (cooling, heating, filtration, etc.)
4. Electrical systems quality and reliability
5. Communications (are redundant services required?)
6. Cleanliness (especially surrounding hazards issues)
7. Physical security
8. Ease of maintenance and service for all building systems without disrupting store operations.
9. Etc.

Depending upon the owner's internal resources, engineering competence of the retailer and the criticality of the building in meeting business objectives, it may be necessary to use a professional engineer to perform the due diligence evaluation.

Investment Performance ROI and TCO

For entry level and lower volume retailers, defining the operational performance requirements should utilize, at least to some degree, ROI and TCO analyses. Numerous models and consulting services for these analyses are available through GRI (an IDC Company), NRF, RSR, Gartner RIS, and others. Well defined needs (near term and long term) help assure alignment with business needs and constrain the costs of procuring, implementing and maintaining the required RMS technologies.

In this regard, the GRI paper "Understanding Total Cost of Ownership in Building Advanced Store Systems Business Case" is a helpful beginning. Figure 9 outlines the essential

assessment areas and the store systems TCO Component Model. A more detailed use of the model is required by medium and large retailers. Without at least a top level review as outlined by the GRI paper, the retailer is exposed to both short-term and long-term disappointments.

Referring back to Figure 1, and the building environment section above, it is important to pay appropriate attention to the bottom layer of the pyramid, especially before any spaces are leased or purchased. Support infrastructure up-fits to meet the needs of the business are potentially expensive and need to be in the budget before a lease or purchase is consummated. If current staff is not qualified to do the assessment, have a professional engineer perform the required services.

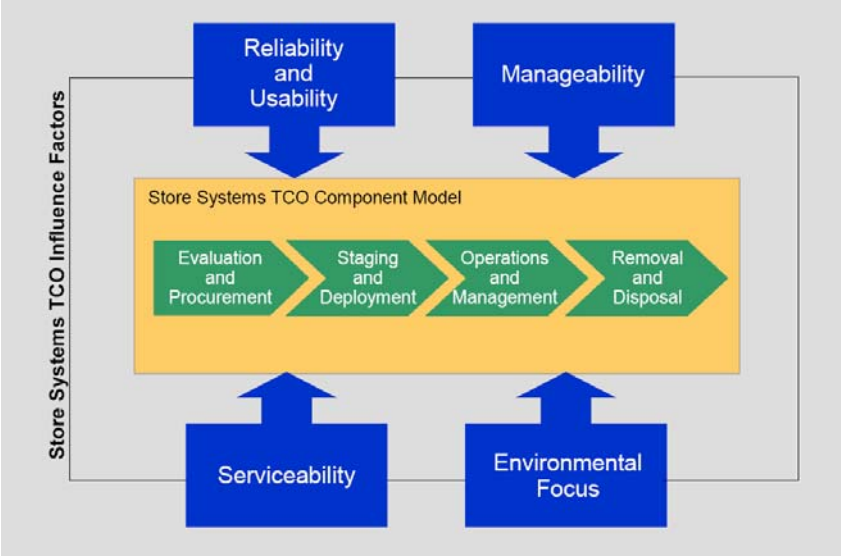

Figure 9. TCO View of Store Systems Source Global Retail Insights, 2008

For new retailers procurement of their POS workstations is a key decision with long-term implications. While the up-front costs are certainly an important consideration, there are downstream ownership cost factors that will far exceed initial cost considerations. These are made obvious in the referenced TCO white paper.

Initial investment expectations, costs of ownership analysis and bottom-line contribution assessments are the financial measures needed to obtain organizational support and also, protect the new, often less experienced POS/RMS owners and users.

The fundamentals discussed in this paper should help.

21C Owner and End User Options

Retailers, from the smallest to the largest, utilize various combinations of the example approaches outlined here. Each has characteristics that are well documented in the literature. The goal here is to summarize the advantages of each approach.

Procure Integrated Systems (HW and SW)

This is an attractive option for retail stores with minimal experience in Point of Service hardware and software. Purchasing an integrated system where the hardware and software are assembled, tested, serviced, and maintained by a single source can greatly simplify purchasing and implementation. This approach can be of value where the retailer has little time for learning, training, etc. due to other store startup issues. Words of caution: The

retailer should apply great care to determine the software requirements, both for day one and the foreseeable future. Software that is short on performance (especially speed and capacity issues), adaptability and reliability quickly becomes a liability. In general, the initial POS hardware and software capabilities should far exceed initial requirements and those expected for the next 3-5 years. Characteristic speed and reliability capabilities of the initial software (and hardware) must be adequate to support growth in volume and addition of registers, servers, etc. to support planned growth. Speed and reliability weaknesses in initial hardware/software purchases will show up early and may require substantial investment to remedy.

A simple systems design rule that applies: The basic capabilities of each building block of the system must far exceed any intended use/requirement of each capability in order to assure long-term performance. Studies indicate that first-cost-to-TCO comparisons for POS/RMS acquisitions show first cost to be small compared to the long term costs. Make room in the budget for good initial acquisitions. It pays off in the long term.

Procure SW and HW Separately and Integrate

The obvious advantages of this approach allow the retailer to optimize POS features, cost/benefit analysis, etc., while potentially reducing both the near-term and long-term costs.

This approach also allows greater flexibility in system definition and allows initial custom SW development and testing prior to installation.

Since hardware and software are separate purchases, the warranties and maintenance & service agreements are with separate suppliers and could be issues when problems occur with the POS or RMS. Clearly defined (contractual) lines of responsibility are helpful, but the problem will often be in determining whether a problem is hardware or software. Working with providers that have a well known track record of solving problems and committed to getting the retailer back in operation, *then* resolving disputes on issues of who pays is worth the search.

Develop Applications Internally (using purchased packages as baseline)

The obvious advantage of this approach is the familiarity the owner has with operating needs and their existing systems. If the internal resources are adequate and capable of developing, documenting, testing, deploying, and maintaining new applications in a timely manner, the approach can make good business sense.

A word of caution: Current studies indicate that retailers with substantial, competent internal resources increasingly have difficulty in delivering new applications on time and on budget. The pace of change forcing the new applications is increasing and there is no evidence that the trend is slowing.

SaaS

As stated earlier, SaaS is becoming very attractive due to the technology advances being made in hardware and software across the enterprise and the internet. The next level of the internet is coming on line quickly. Speed, reliability, security, depth & breadth of services, etc. will be increased at a blistering pace and the costs are going to become increasingly attractive.

Retail SaaS for all tiers of retail operations will be a beneficiary of this rapid improvement in the internet and computing HW and SW. SaaS will reach throughout the retail operation from the customer to suppliers. Fast, flexible, seamless, reliable, and secure services will all be available from a menu and quickly.

A SaaS feature worth considering for all users: The owner does not invest in hardware, software, facilities, staff, etc. to support the RMS infrastructure; all that is left to the SaaS supplier. To accomplish similar results via the alternatives discussed in this paper and others requires taking on a lot of overhead including very talented people, especially when performance and reliability (total systems availability) requirements are high. Often the talent is simply not available.

Combinations of the above

Large retailers utilize versions of all these combinations, many by default. Good technology or applications alternatives were often not available when specific functions were required. Retailers consequently developed what they needed and they grew their new capabilities based on those initial steps, hence, legacy systems.

Legacy systems of any kind have some characteristics that are difficult or impossible to overcome:

1. Age: Reliability and performance are compromised at a predictable rate. Maintenance and service costs increase.
2. Support: Older systems (hardware and software) require more support and suppliers eventually will not support the product even at high costs.
3. Compatibility: Hardware and software (out-of-date) compatibility issues begin to affect systems performance and reliability.
4. Documentation (quality) tends to degrade for facilities, hardware, and software.
5. New application delivery times and costs tend to increase precisely when rapid change requires more to be accomplished much faster just to remain competitive.
6. Expertise that developed the original systems is gone and no longer available.
7. Other issues that are more user specific.

Summary

As stated, this paper is an introduction to issues affecting POS and RMS performance requirements in the 21st Century. Considerable effort was put forth to introduce the importance of reliability, speed in POS and RMS systems. The next two decades of technological advances will exceed all that have gone before in the last 250 years. Advances in base digital technology, computing technology, communications technology, communications infrastructure (internet), etc. will enable retailers from around the world to compete in every market around the globe easily.

Though aware that a supplier may be located in New York, Brussels, Munich, Budapest, etc. it will not matter. Using the internet, the 21st Century customer can order the item they want, at their price, pay in their own currency, and have the product delivered to their home within hours. The author does this routinely and the process works very well now and is becoming easier to do everywhere rapidly. Competing in that arena with the bricks and mortar option will require top-notch customer service at every level of the enterprise. Every successful strategy and tactical operation will be entirely dependent on robust RMS technology.

The speed, reliability and adaptability of 21st Century RMS will need to be extraordinary by today's standards. These same traits will become ordinary in the global community. Failure to participate in the technology advantages being made available through these new capabilities will be increasingly punishing to bottom line performance. Participating in 21st Century technology performance growth does not assure success, but it does keep the playing field fairly flat and can be significant in creating an advantage in satisfying the unsatisfiable customer.

Reliability and systems performance have not, historically, occupied a very important place in the retailer's hierarchy of needs. To help rethink that, ask these questions: 1) With my RMS down (not available) what can be done? Answer: Not much. 2) Of those things that can be done what is their value? Answer: Not much. 3) And finally, day in, day out, how much of the business flows through the RMS infrastructure? Answer: All of it.

POS and RMS technology is essential to retail competitiveness. Speed and reliability need to be key factors in selecting RMS technology tools for the 21st Century.

Robust POS software with a whole new level of fault tolerance and greatly extended functionality will be a key enabler for bricks and mortar retail operations, regardless of size.

Disclaimer

This paper is an educational document to introduce the reader to important POS and RMS systems characteristics to be considered by the 21st Century Retailer. The concepts put forward are quite general, greatly simplified and are not adequate to assure success in defining POS and RMS systems strategies without additional expert guidance. None of the concepts presented in this paper are treated with the depth to function as the sole tool to develop business strategies or business concepts. GoldTech, Inc believes that the information supplied is accurate, but accepts no liability for its use without the documented, direct council and guidance of GoldTech, Inc.

Recommendations and Assistance

This paper presents a broad array of issues facing the 21st Century Retailer. Many of the areas introduced can be complex and confusing, depending upon the experience of the owner/end user and the complexity of the systems involved.

Always locate a qualified professional to assist with the development of the details presented in this paper.

For those readers needing additional information or specific guidance, see the Appendix.

Appendix

A broad range of topics were introduced in this paper, many are quite technical. A number of references are listed below that may be of assistance.

Should further assistance be required, please visit the GoldTech, Inc. website at www.goldtechservices.com.

1. The Toxic Terabyte, IBM, IBM Global Technology Services, 2006
2. Understanding Total Cost of Ownership in Building an Advanced Store Systems Business Case, Global Retail Management, January 2008
3. Software as a Service and the Need for Speed, Benchmark Study July 2007, Retail Systems Research
4. Retail IT Budgeting Study, AMR Research, 2006
5. The Future of Applications Delivery In Retail, Retail Management Research, 2008
6. Business Intelligence Crosses the Channel, Gartner/RIS, April 2008
7. Seizing the In-Store Opportunity, IHL Group, 2008
8. *An Insider's Guide: FMCG Retailer Strategies for 2008*, Retail Strategies, AMR Research
9. First Approximation Reliability Analysis of Simple Series Systems, GoldTech, Inc.
10. First Approximation Reliability Analysis of Simple Parallel Systems, GoldTech, Inc.
11. Example: Simplified Reliability Calculations, GoldTech, Inc.
12. The Law of Accelerating Returns, Ray Kurzweil, KurzweilAI.net

The list is brief, but should be helpful to those needing a more in depth understanding of the ideas presented in this paper.