Value and Acceptance of System Dynamics in Business: Business Owner as SD Practitioner Perspective

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Abstract

This paper is written by a practicing System Dynamics modeler and mid size business owner and manager. Using one modeling example, this paper describes the acceptance and usefulness of the modeling process and insights as a practical business tool. In the author's experience, personally using rigorous SD modeling, especially careful use of stock and flow concepts, to describe and gain insight into dynamic business issues is effective and valuable to his business. The modeling efforts generated several critical insights that were used to alter policy to the advantage of the business. However, communicating these insights beyond a few close and involved employees was met with significant resistance, especially when "System Dynamics" or "Computer Modeling" was central to the discussion of insight generation and policy formation.

Introduction

Refrigeration Sales Corporation (RSC) is a fourth generation privately-held business providing wholesale products and services to the heating, ventilating, air conditioning, and refrigeration (HVACR) trades in parts of Ohio, Pennsylvania, and Michigan[1]. With thirteen locations, over 130 employees, and more than $80M (USD) in annual wholesale revenues, RSC has become a large regional business serving thousands of mechanical contracting firms. RSC purchases products from about one hundred manufacturing firms and then provides immediate product availability, financial credit, 24 hour support, and industry training required by its contractor customers. RSC does not manufacture any products, nor does it install or service HAVCR applications in the field.

Since the year 2000, RSC has been led by the author, its President/CEO. The author came to RSC in 1993 with ten years of business experience (outside of the HVACR industry) and a Masters of Business Administration (MBA) from Duke's Fuqua School of Business. Beginning in 2001, the author became an avid student of system dynamics after he attended a week long executive education class led by John Sterman of MIT. the authro has spent the past 12 years creating a series of models surrounding the HVACR industry and business of RSC. The author received his Maters of Science in System Dynamics from WPI in 2011.

[1] While RSC serves a three state region, US national data will be used in this paper. Industry data for RSC's specific territories is considered proprietary while US AC industry data is available on the internet as cited. The overall trend for the two data sets is sufficiently similar to make this substitution inconsequential.

System dynamic business models were created and used at RSC to create more effective business policy and answer questions such as: At what pace should RSC expand its operations? At what level should RSC invest in appropriate technologies? How long does it take to break even when opening a new store location and why? How can RSC increase the efficiency of its marketing budget? What impact will proposed EPA (the US Environmental Protection Agency regulates refrigerant gases) and DOE (the US Department if Energy regulates equipment efficiency standards) policy have on RSC's business? What level of customer credit is most effective to grow business while minimizing bad debts? and What are the likely future industry scenarios?. This paper will focus on the modeling work done to explore the last question: What are the likely future industry scenarios? This question was chosen for this paper because the modeling work generated opportunities to share the modeling insights with a large group of RSC constituents.

Air Conditioning Dynamics: The Lifecycle of a Durable Good

In 2001, the RSC management team was facing what appeared to be slowing growth in the US air conditioning industry. Although the US air conditioning industry routinely experiences year-over-year ups and downs (in addition to a high degree of monthly seasonality), for the past 20 years average annual unit sales growth had been in excess of 8%. As a result, much of RSC's annual budgeting and planning process anticipated growth in the industry. Because wholesaler expenses are largely semi-fixed (facilities and people), wholesaler margins are extremely sensitive to a decline in sales. However, it is widely believed that any reduction in wholesaler capacity (reduction in facilities or people) creates a significant risk of missing the upside of robust growth after a downturn.

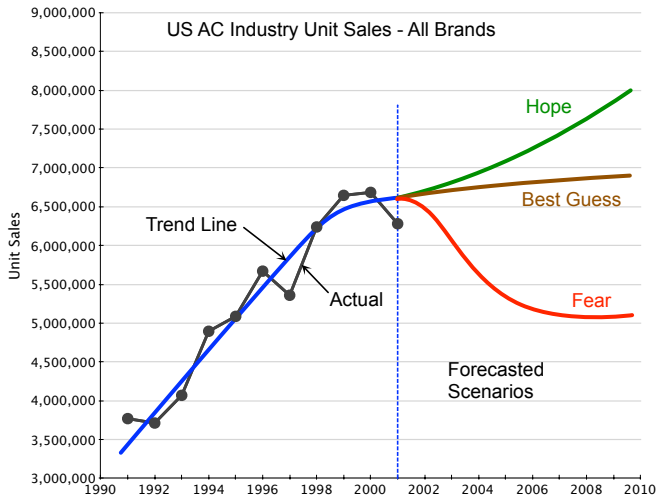

Figure 1: US Air Conditioning Annual Unit Sales prior to 2002[2]

[2] Air Conditioning, Heating, and Refrigeration Institute, 2012, "Central Air Conditioners and Air-Source Heat Pumps Historical Data"

After discussing the sales trend with business partners, the RSC management team could think of three possible future scenarios: continued but slower annual sales growth ("hope" scenario was a favorite of suppliers and customers), leveling off of annual sales ("best guess" scenario was RSC management's favorite), or a contraction in annual sales (the "fear" scenario was offered by an RSC Board member). To explore the likelihood of these future scenarios a series of system dynamics models were built for exploration and discussion. An example model is shown below.

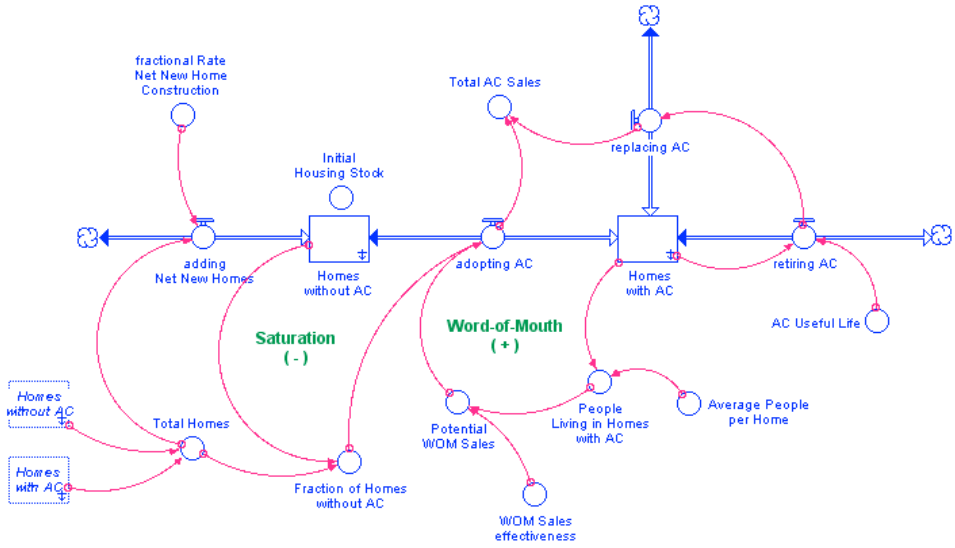

Figure 2: Air Conditioning Industry Dynamics: Bass Diffusion with Replacement

The model behavior shows the stock of houses without AC (blue in the graph below) declining and the stock of homes with AC (red in the graph below) increasing as AC is adopted. There is a steady state of homes without AC and continuous growth of homes with AC as net new homes are added to the system.

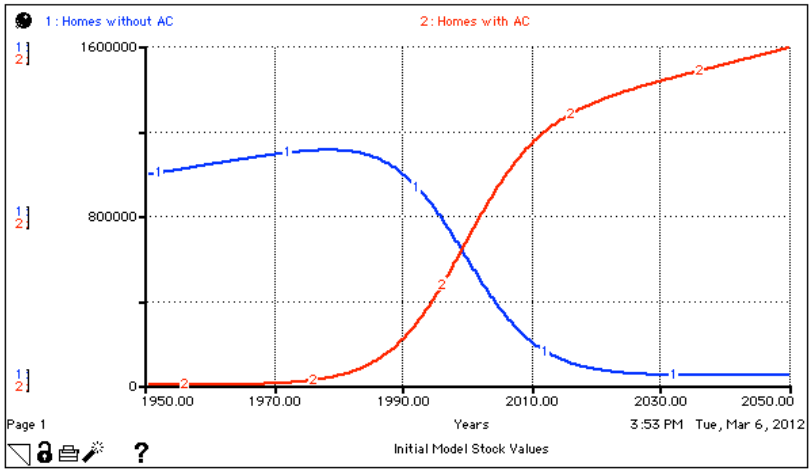

Figure 3: Air Conditioning Industry Dynamics: Primary Stocks

With reasonable parameter values, the model behavior shows that the total annual unit sales flow (green in the graph below) declines (by as much as 15% to 20% - black in the graph below) before reaching a sustainable replacement rate. This most closely replicates RSC's future fear scenario. The RSC model confirms work published in 1969 by Frank Bass where he describes what has become known as "Bass Diffusion"[3] Included in this work was a conclusion about how consumer durable sales change over time: "… With consumer durables … Sales grow to a peak and then level off at some magnitude lower than the peak."

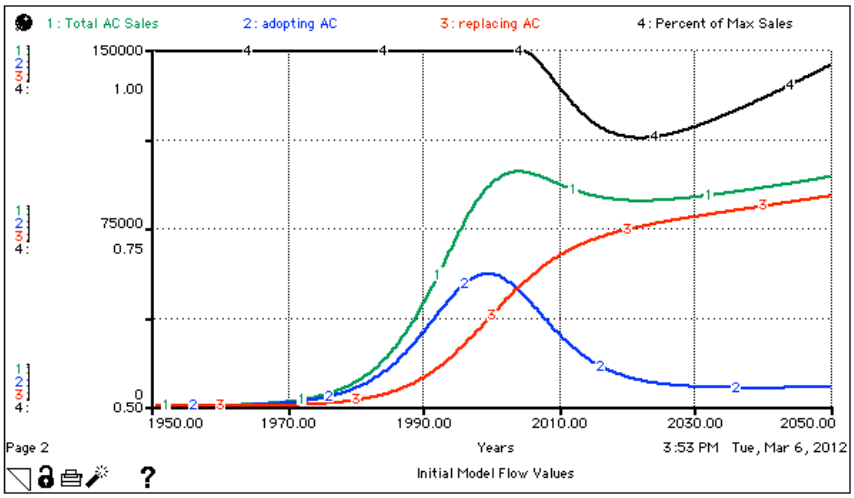

Figure 4: Air Conditioning Industry Dynamics: Primary Flows

Based on this modeling work and the discussions within the executive management team, RSC significantly changed its five year strategic plan from expansionary to expense reduction through consolidation, process re-engineering, and technology adoption. At a time when annual air conditioning unit sales continued to grow at a record pace (2001 through 2005), the RSC management team improved processes and invested in technologies while reducing the workforce by 15% and the facility square feet by 30%. Beginning in 2006, the US air conditioning annual unit sales began an unprecedented decline lasting four years and contracting annual unit sales by over 30%.This is shown in the updated US air conditioning unit sales graph below.

[3] "A New Product Growth for Consumer Durables", Frank M. Bass, Management Science. Vol. 15, No. 5, 1969.

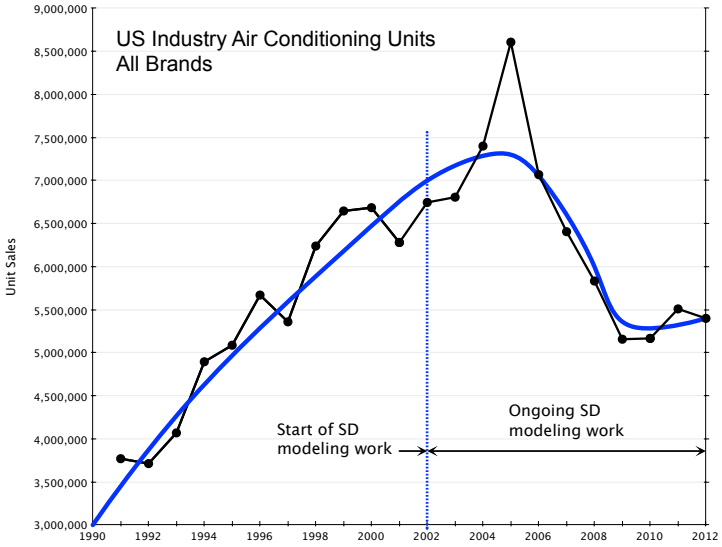

Figure 5: US Air Conditioning Annual Unit Sales through 2012[4]

Important Model Insights

Although the modeling work was done by RSC's President, the RSC executive team routinely challenged and discussed the emerging model insights. The subject RSC SD modeling effort is ongoing and has explored such enhancements as: population growth, air conditioning affordability, contractor formation and exit, and inter brand rivalry. The most important insight, however, does not rely on any of this additional model structure. The most important insight is that high product durability mathematically requires a contraction in the annual product sales before a sustainable annual replacement sales rate is reached. This result is independent of economic factors such as interest rate, consumer confidence, or changes in housing construction.

Total annual unit sales are the sum of adoption sales (installing where there is no current AC) and replacement sales (installing to replace an expired AC). Adoption sales are largely a function of the size of the available housing stock as well as adoption rates (infectivity or word of mouth effectiveness). Holding these factors constant, the pattern of adoption sales does not change from the blue bell shaped curve in figure 4 above. If the product is infinitely durable, total sales equal this bell shaped curve since there are no replacement sales. In contrast, if the product has short durability, then it is replaced frequently (red S-shaped curve in figure 4 above). If the S-shaped replacement curve is sufficiently large relative to the adoption curve, then total annual sales resemble the S-shaped replacement sales. By definition, durable goods have a long durability making replacement sales small in comparison to adoption sales resulting in the contraction of total annual unit sales prior to reaching the sustainable annual unit replacement rate (green complex curve in figure 4 above and echoed by the actual unit sales shown in figure 5 above).

[4] Air Conditioning, Heating, and Refrigeration Institute, 2012, "Central Air Conditioners and Air-Source Heat Pumps Historical Data"

Significant modeling efforts over time and the resulting conversations among the RSC executive team created confidence in this insight. This confidence led RSC management to reduce expenses and to reduce total capacity during the air conditioning market expansion from 2002 through 2005. While maintaining this course was difficult during this expansionary period, the confidence created from developing, challenging, and changing the model caused RSC to reduce expenses and marshal significant resources during this period, ultimately preparing it for the predicted industry contraction. It is interesting to note that while the RSC executive team was confident in an eventual contraction in annual industry sales, the timing of the contraction was highly uncertain. (While annual sales flows are relatively well known, available estimates of the installed base of air conditioning units are highly suspect.)

Getting to and understanding this insight required an accurate “operational structure” of how residential air conditioning units diffuse into the market. Dividing the housing stock into homes without AC and homes with AC required an “adoption” flow and a “replacement” sales flow. These modeled sales flows contrasted significantly with the common industry insider flow segmentation of “add-on and replacement” and “new home construction”. The industry uses these two sales flow segments because they parallel the sales and marketing process.

“Add-on and replacement” sales are handled by a segment of customers called “retail dealers”. Retail dealers call on homeowners who are looking to adopt air conditioning or perhaps replace an existing defunct air conditioner. Apart from anecdotal evidence known only to the retail dealer, the sales channel does not track add-on sales (adoption) separately from replacement sales. “New home construction sales” are hare handled by low cost, high volume new construction contractors used to working in unoccupied construction sites. Marketing and selling to retail dealers is significantly different then new construction contractors. The segmentation used by industry insiders is very useful for understanding and penetrating these two very different sales channels.

Adding new home construction into the RSC model yielded the second most important model insight: similar to air conditioning units, homes are also a durable good and have a useful life. While the AC industry players routinely think of new homes as an increase in the size of the installed base of AC, the RSC model implies that the more homes with AC, the more likely that an AC installation in a newly constructed home is indirectly replacing an AC installation in an old home at the end of its useful life. Thus new home construction sales become replacement sales and not adoption sales.

While an AC unit sold into a newly constructed home adds to the annual unit sales flow, it does not necessarily represent growth in the installed base of AC units. Ultimately, the region’s population is what determines and supports the housing stock and thus the installed base of residential AC.

This is a subtle but significant realization. Erroneously counting all new home construction with AC as an increase in the installed base of air conditioners greatly exaggerates the size of the installed base over time. This inflated installed base of air conditioners exaggerates the size of the required annual replacement flow as AC units

are forecasted to expire. It is this author's belief that the inflated estimate of the installed base of air conditioning units has caused a significant over investment in AC production, sales, and installation capacity in the US.

The Opportunities and Consequences of Owning these Insights

By far the biggest opportunity of owning these insights was proactively planning for an anticipated market contraction. When the contraction began, RSC had already incurred the necessary reduction in expenses to remain profitable. With the insight that the industry would be over-capacity, RSC had improved the quality of credit extended to customers in anticipation of an increase in customer bankruptcies. In addition, RSC SD model enhancements had revealed additional insights concerning marketing expense efficiencies in an over-served environment. Because the sales contraction did not occur for several years, RSC was able to collect resources in preparation for leaner times. These resources proved valuable after the industry contraction began enabling RSC to obtain additional product lines from failing competitors, open or acquire new store locations in desirable markets, and hire some of the industry's best sellers from weakened competition.

There were also several negative consequences of owning these insights. Most significantly, RSC management was not expecting the industry to grow so rapidly through 2005. It is management's belief that while every effort was made to meet the peak demand periods (typically June and July), some business was lost to the competition as customers balked at slow service or longer store lines. To overcome some capacity issues, RSC allowed unprecedented levels of overtime and hired some temporary help to get through the busiest of times. These actions added expense beyond what would have been required with less consolidation of operations.

Because RSC management had a significantly different view of the future AC industry than its employees, customers, and suppliers, management spent significant time explaining its actions. (A detailed description of many of these discussions will be discussed in the next section.) As a result of differing viewpoints between RSC and one or more critical suppliers, there were instances where resources that would have been available to an "expanding" RSC were removed by the supplier. One such example is marketing funds. Typically, an HVAC equipment supplier will make "coop marketing funds" available for local wholesaler marketing program expenses. Use of these funds is contingent on the type of expense and the message being delivered to the market. When RSC's understanding of what would be most effective in the market differed significantly from that of the supplier, these funds were reduced or eliminated leaving RSC to fund 100% of some marketing programs.

Overall, the benefits of having a confident vision of the future and then acting on the resulting opportunity outweighed the realized downside due to unknown timing. As will be discussed in the next section, the overall communication and understanding of the dynamic situation described by RSC's modeling work was not eagerly received, nor well understood by many of RSC's stakeholders.

Conversations with Stakeholders Resulting from Sharing these Insights

In this example, the future scenario predicted by RSC's modeling work was an overall negative message: the market will contract significantly and there is nothing that can be done in the short term to prevent it. While knowing this in advance was a positive for RSC managers and shareholders, the overall message is quickly perceived as a negative by other stakeholders. The prediction of a contraction is also in stark contrast to the growth that the US air conditioning market had been experiencing for decades. Perhaps the most difficult message is that durability alone determines the size of the contraction and product durability is determined solely by air conditioning manufacturers. (Today's experienced US air conditioner durability is 12 to 23 years, averaging 17 years nationwide.)

While most everyone was quick to admit that nothing grows forever, few were willing to consider any argument that the air conditioning market will shrink significantly and for an extended period. The prevailing mental model of air conditioning "maturity" continues to be S-shaped growth typical of low durability goods markets. Those who forecast are using historical sales to calculate the installed base, and then using the calculated installed base to forecast future sales. Furthermore, presenting a new mental model based on the separation of adoption and replacement sales (contained in "add-on and replacement sales" by industry insiders) and seemingly ignoring new construction sales (a part of replacement sales in the RSC model) represents a significant shift in understanding.

Even now with an unprecedented AC unit sales contraction behind us, industry insiders are reluctant to embrace the RSC causal explanation. The prevailing causal explanation relies on unfavorable economic factors such as consumer confidence (repairing AC not replacing it) and the "housing bubble". Of course these arguments require annual air conditioning unit sales to recover when economic factors recover. As the AC flow contraction persists, it is offered as evidence that the economy is still not well (for durable goods). The idea that a controllable product design criteria such as "expected life" is the key determinant of the downturn is far less tangible than the endless stream of reported daily economic factors beyond anyone's control. The belief that recovery could happen at any time is causing excess manufacturing capacity to persist when it will not be needed for decades.

Perhaps the clearest example of entrenched mental models are those at a prominent wall street investment bank. The author has been working with an investment bank analyst in an effort to improve their spreadsheet modeling of the air conditioning industry. The current spreadsheet model contains hundreds of flows combined in sophisticated ways. What is most striking is that there is no provision for AC adoption or installed AC mixing because there is only one stock value used in the calculation. That stock is the accumulated error representing the difference between model predictions and historical data. The stock is called: "pent-up demand" supporting the idea that when the economy improves, there will be a flood of AC sales. The author has provided SD models as well as hours of meeting time to discuss and describe the differences

between RSC's SD model and the investment bank's spreadsheet model. Perhaps improvements will be realized in the future as a result of these conversations.

RSC's suppliers have similar spreadsheet forecasting models which they have been reluctant to openly share. Several individuals working for RSC suppliers have been introduced to the RSC causal explanation more than once over the past several years. This was done in conversation, in writing, and in formal presentations of the RSC SD models. Some of the reactions from supplier stakeholders follow:

- Market Analyst for a major equipment manufacturer: When asked why the air conditioning sales downturn has persisted: "(Our) models show a large potential for the next 10 years based on the surge in sales from the late 90s to mid 2000s, but I think a substantial number, maybe 20% to 30%, will never be replaced due to affordability issues. I believe the middle class is under severe duress and cannot continue to pay for central a/c as they have in the past, so I see many units reaching the end of their life that will never be replaced."

- Vice President of a major OEM parts manufacturer: After a thirty minute presentation of the RSC causal model: "I am concerned that we are not considering housing demolition (with AC) in our models."

- Financial controller from a major equipment manufacturer: Upon re-meeting at an industry event: "Are you the guy who has the crazy idea about why the AC market has contracted? How have your predictions worked out?" After replying that the predictions have been accurate in magnitude, this person was asked if they remember the causal argument that was made. "No, but I am sure that it was interesting."

- Plant Manager of a major equipment manufacturer: After a brief description of how long product durability could cause a contraction in annual sales: "We could never reduce the useful life of an air conditioning unit. People would not buy it."

- Marketing Manager of a major equipment manufacturer: After a thirty minute presentation of the RSC SD model: "That is interesting, but I came here to learn what we can do today to increase air conditioning sales."

- Sales Manager of a major equipment manufacturer: After a brief explanation of the causal argument: "Whether the air conditioning market is up or down, we need more share of market. What is RSC doing to gain market share?" (Manufacturers need market share more than ever because of excess capacity.)

- President of a major equipment manufacturer: After a five minute verbal explanation of adoption versus replacement sales flows: "That sounds interesting, please send me your thoughts in writing." This was done, but no reply or followup was ever received.

Because the overall model implications are perceived as negative, conversations with RSC customers have been limited to the implications of slowing growth in the air

conditioning market. The message from the RSC team to customers did not contain causal model details, but focused on ways to proactively market maintenance and repair services in an effort to form lasting relationships with the homeowner. RSC customers have first hand knowledge that adoption sales are nearly completed, making replacement sales the future of the business. Regardless of this knowledge, the market contraction put record numbers of small air conditioning contracting firms out of business between 2006 and 2010.

Conversations with RSC employees focused on efficiency and cost reductions. Most employees outside of the executive team were not interested in the reasons for reductions, just concerned for their jobs. The reason for business consolidation and reductions became known as “the maturing AC market” and how RSC needs to change because things are “not how they used to be”. Now that air conditioning sales have leveled out, employees like to hear that the sales contraction was a required one-time event that will not repeat itself (until someone invents a better air conditioner!).

RSC has other stakeholders such as shareholders and lending institutions who have been generally very curious about management’s causal perspective on the air conditioning industry. These stakeholders have been supportive of management’s view and the actions that have been taken as a result. These stakeholders generally believe that management’s strategic planning and the actions that followed created additional profitability.

Overall, RSC management has had limited success engaging most stakeholders in the details of the causal arguments contain within RSC’s SD models. Even as recorded air conditioning sales support the model predictions, contrasting mental models remain intact. In fairness to reluctant stakeholders, RSC management’s primary job is running the business. As such management has not created a focused plan to educate the world on these causal arguments, with one exception: in 2008 an RSC case study was written for the purpose of educating business school students Bass diffusion and some basic system dynamics. The RSC case study has been successfully used for the past five years at institutions such as Duke’s Fuqua School of Business, the University of North Carolina’s Keenan-Flagler School of Business, and most recently at UCLA’s Anderson School of Management.

Impact of Being a Business Manager with Model Building Capabilities

So what is the value of being a business owner/manager with model building capabilities? The author could describe many instances where building high quality models to address top level concerns of the business was indeed valuable, providing confidence about how certain dynamics systems of interest work and preventing the pursuit of less effective or more costly business policies. There are an endless number of additional applications for high quality system dynamic modeling.

An RSC executive team member who is not the author would describe situations where the time spent exploring and discussing subjects being modeled was instructive and rewarding. But, they would also express a frustration that successful businesses

have a bias towards action. Do what works; if it doesn't work, do something else - now; then repeat the process. Being right 70% of the time is a terrific average and keeps things moving. This team member would admit that some business decisions put significant resources at risk and deserve more analysis, but would hasten to say that most business decisions should be made swiftly, and then be measured and changed if required. This process requires far more action and measurement than analysis of options. In many cases, the selection of analysis or action is a matter of personal preference.

With this in mind, the author believes that much of the value generated by being a qualified system dynamics modeler stem from the types of issues faced by a business owner and manager. High risk strategic business issues are well suited to a more detailed causal understanding. Being able to describe and discuss large strategic issues with detail, confidence, and clarity has significant advantages. In contrast, issues facing a warehouse worker may be better suited to the action-measure-repeat strategy, unless negative outcomes become chronic and detrimental to the business. In this case, the bias towards action is preventing a clear understanding of how the system is working making an SD engagement more valuable.

The language and tools of system dynamics provide a powerful way to explore these kinds of issues risk-free (except for the passage of time). With practice, observing generic patterns of systems with similar structure creates immediate insights into "new" situations and enables more confident analysis. Just the basic ability to separate the components of a complex situation into stocks and flows (without considering feedback) can provide significant insight into what should be inspected further. Each of these basic skills provides a curious person with the confidence to explore difficult situations.

A frustrating side-effect of modeling as a business owner-manager is the occasional insight gained by accident that has no real bearing on the welfare of the business. It is tempting to find a "place" to use the insight, or to find someone to teach about the insight. In the author's experience, this rarely works out. No matter how relevant or valuable the insight seems to be, if it was not requested or generated by a stakeholder, it is most often dismissed.

An example of this would be another durable good: automatic standby electric generators. An automatic standby electric generator is installed at a home or business to provide automatic backup electric power when utility power becomes unavailable. The generator continuously monitors utility power, starting itself up when a utility power outage is detected. Because it is permanently connected to selected household circuits, there is no intervention required by the homeowner. When utility power is restored, the generator shuts down and waits for the next opportunity to be of service.

Standby generators are a very durable good and are early in the product adoption phase. Lessons learned with the RSC SD model of durable goods should apply to this product, although it is not yet near the point of air conditioning market saturation. The RSC model demonstrates that the more durable the good and the faster the adoption rate, the more severe the contraction in unit sales. In an attempt to share this insight,

the author had an interesting conversation with two executive managers of a leading US standby generator brand. The conversation focused on why they should be thinking about controlling the adoption rate as well as the product durability in order to smooth the inevitable sales contraction. It was a difficult and unsatisfying conversation because of the entrenched S-shaped growth mental model and because saturation of standby generators is likely to occur beyond the retirement dates of these executives.

Another example of this would be an RSC SD model developed to manage inventory of air conditioning units containing R-22, a refrigerant gas being phased out by the US EPA. The core questions to be answered by the model where about how much inventory to purchase and when to stop purchasing it. The model helped to answer these questions, but it also provided insights into the types of policies that would be effective in managing and reducing the amount of R-22 refrigerant gas that escapes into the atmosphere. While interesting, the RSC executive team has little influence on such policy and nothing to gain in business by spending valuable time promoting such insights. As a concerned global citizen, this was a frustrating experience.

In summary, system dynamics modeling is a valuable tool for business owners and managers to use. The author has used system dynamics concepts and rigorous system dynamics modeling to crete business value. In addition, there is personal satisfaction in being able to recognize generic structures and patterns of behavior whether they directly impact the business or not. The author believes that many of the world's most complex issues require these tools in combination with people of influence who are experienced at using them.

Selected References

Biography

Warren Farr received his Master of Science in System Dynamics from Worcester Polytechnic Institute in 2011. He has been working in the heating, ventilating, air conditioning, and refrigeration industry as a wholesaler since 1993. Prior to learning to operate a wholesale business, Warren worked in the computer industry developing and marketing network control products, and as a contractor to the military developing communication and targeting systems. He also has a Bachelor of Science degree from Duke University and a Master of Business Administration also from Duke.