Smart Manufacturing in Small and Medium Manufacturers in Nevada: Survey of Drivers, Barriers, and Technologies

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EXECUTIVE SUMMARY

Introduction

Smart manufacturing (SM) solutions are a key part of the fourth industrial revolution, or Industry 4.0. SM integrates technologies to improve communication between people and machines in order to enhance decision making, advance energy efficiency and productivity, and reduce waste. Small and medium manufacturers (SMMs) potentially benefit from adopting these technologies, but may also face greater challenges adopting and realizing the potential of SM than larger companies. Due to scarcity of targeted research, little is known about how SMMs view smart manufacturing and what their experiences have been with it, which is key to developing and implementing effective scale-appropriate solutions. In the US, surveys conducted by consulting firms or interest groups on the topic typically focus on larger and already engaged manufacturers [see for example 1, 2-4]; when they include smaller manufacturers, results are rarely presented stratified by enterprise size [see for example 5, 6, 7]. Only a few academic survey studies assessed the status of implementation and uptake of specific technologies and the perspective of SMMs regarding the drivers and barriers of SM in the U.S.

This study surveys representatives of SMMs in Nevada to assess their attitudes toward and experiences with smart manufacturing solutions. Subjects were asked about their companies' readiness level for adopting SM, their workforce training and hiring needs, and the major drivers and barriers to adoption. Unusual for studies of this kind, subjects were also asked about specific SM technologies that are used in their SMMs. Results from this study can be used to characterize the current landscape of smart manufacturing in Nevada's SMMs, and help policymakers target specific barriers to adoption.

Methods

The survey instrument was based on one the UC Irvine research team designed for an earlier project for the Department of Energy [8]. That study targeted SMMs across the U.S., but provided limited data on any one state other than California. The original questions were based on an extensive review of prior studies and replicated existing measures when possible. The team consulted with experts to construct a list of twenty specific SM technologies and designed questions to assess how they have been used or could be used in SMMs. For the current study, some questions and items were omitted to reduce length and new questions were added; those that remained retained the same wording (and scale construction) to facilitate comparability across the two surveys. Topics focused on: 1) level of readiness to adopt new technologies, including current adoption level, 2) experiences with smart technologies currently or previously used in their facilities, and 3) drivers and barriers to new technology adoption.

Data collection for the online surveys was conducted October 2021 to January 2022. Subjects were recruited by email, starting with Nevada Industry Excellence's (NVIE) contact list of Nevada SMMs, and updated to replace outdated contacts whenever possible. Announcements were included on the NVIE website and newsletters. Each company is represented by only one survey subject.

Results

This report presents survey findings for 84 owners and managers of SMMs in Nevada, defined as those with fewer than 500 employees (70% had fewer than 50). Results show a cautiously optimistic level of readiness to adopt SM, with upper level management subjects reporting higher levels of management support (3.7/5.0) than midlevel employees (3.3/5.0). Few companies have fully implemented SM concepts (7%), but 20% have implemented first measures and another 30% are developing adoption plans, showing that more than half of Nevada SMMs are interested moving forward. Together, these readiness measures reveal interest among Nevada SMMs for moving forward with SM solutions, but suggest that their ability to fully adopt lags behind their willingness to consider it.

Staffing needs are a major readiness challenge for Nevada SMMs. Only 18% of subjects report their SMMs have a sufficiently skilled workforce to adopt SM: the majority would need to train existing workers and hire new employees. When asked what percent of their workforce would be affected, the answers were sobering. On average, half of employees would need more training (49%); in 33% of these companies, training would be needed for at least 75% of employees. The majority of companies (62%) would need to replace at least some employees who could not be effectively trained, with 22% needing to replace 25% or more of their current workers. Even more of a concern, 73% of these SMMs would need to hire additional workers (in addition to any replacements) to meet the needs of smart manufacturing. New hires that increase total staff levels is even more costly and difficult than replacing existing workers, so even small numbers in this category can act as a major barrier. To adopt SM, 30% of these SMMs need to add another 1 to 9% of workers to their workforce, 24% need 10 to 19% more, and 18% need 20 to 33% more.

Asked about nine specific work tasks that SM could potentially benefit, the majority of subjects felt that smart manufacturing was either already helping or would be a benefit for most tasks. However, a substantial minority of subjects reported being satisfied with how well low-tech solutions worked, particularly for assigning jobs or tasks (33%), internal communication (28%), and communicating with third parties (25%). This finding provides an important reminder that not all solutions should be sought simply because they are new and technologically sophisticated. Nevada SMMs need to concentrate their relatively limited resources on adopting only those solutions that solve their specific needs

The driver most often cited for adopting smart manufacturing was reducing costs—mentioned by 68% of subjects and reported as the top-most driver by 36%. Improving time-to-market was next for top-three mentions, at 38%, but is reported as a top-most driver only by 13%. The corollary is that the topmost perceived barriers to adopting SM were the additional investment of money (33%), uncertainty about the effects on profits (22%), and time (13%). Put together, these findings illustrate the essential challenge faced by many SMMs: they don't have the money needed to invest in order to save more money, and although they'd like to improve their time-to-market, they aren't confident about getting sufficient returns on their investment in SM.

The survey asked subjects whether their companies were using any of 20 technologies as part of a smart manufacturing solution, and if not, whether they had ever tried or considered that technology and rejected it. All but 7% of these Nevada SMMs use at least one SM technology on the list, with 46% using 1 to 4, 35% using 5 to 8, and 12% using 9 to 13. SMMs with fewer than 20 employees used significantly fewer SM technologies on average (3.6) than companies with 50 to 499 employees (5.4). The SM technologies used most often are mobile phones (69%), cloud computing (54%), handheld scanners (48%), cybersecurity (48%), and tablets (45%). Several higher-end technologies were rarely used or even considered by these SMMs, including smart glasses and augmented reality (AR) and virtual reality (VR) headsets. Subjects reported moderate satisfaction with and positive worker reaction to SM technologies already adopted, but the averages include large minorities with neutral or negative reactions. Overall, variations in evaluations of certain solutions support the idea that SMMs can benefit from targeting their relatively limited resources on specific technologies for specific needs rather than embracing the full spectrum of smart manufacturing.

Conclusions

This study shows both how SMMs in Nevada can potentially benefit from smart technologies and the extent of the serious challenges they face when adopting this digital transition. Overall, these results support the idea that SMMs, even more so than larger companies with more flexible resources, should focus on integrating specific technologies tailored to their specific needs rather than attempting to embrace the full spectrum of smart manufacturing at once. This study further adds to prior research by asking about companies' experiences with specific tools. In this study, Nevada SMM representatives expect substantial training and staffing replacement needs for fully adopting SM, which supports two complementary approaches: help them directly with training, and help them start with small steps and ramp up slowly. Put together, the current findings offer clear implications for what would help Nevada SMMs move forward now. Specifically:

- A focus on integrating accessible, more common technologies into smart manufacturing solutions, such as mobile phones, handheld scanners, tablets, cloud computing, and cyber-security – these are used more often by SMMs, have generally positive responses, and given their ubiquity, may cut down on training needs.
- Attention to the tasks that specific SMMs would benefit from digitalizing; embrace hybrid solutions that maintain old school approaches that still work, rather than pushing all-or-nothing options.
- Financing assistance at the early stages to help pull SMMs out of a cycle of stagnation, where they can't save money with SM because they can't invest money in new SM equipment and training.
- Useful tools to advance adoption that help compensate for lack of trained personnel, time, and money, including clear, actionable information and guidance on how to achieve solid returns on their investment and measure their results.
- A range of accessible workforce training options aimed at smaller manufacturers at varied levels of readiness and with varied needs.

In summary, these results inform the development of strategies, outreach, and technological solutions that are affordable and easily adaptable for SMMs by providing quantitative evidence of what SMMs need that many in the field have seen anecdotally. More research could provide an even better understanding of where SMMs are in their transition to smart manufacturing and what problems they have that would be most responsive to new technology.

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TERMS AND ABBREVIATIONS

Term/Acronym	Definition
AI	Artificial intelligence
AR	Augmented reality
CalPlug	California Plug Load Research Center, University of California, Irvine
CESMII	Clean Energy Smart Manufacturing Innovation Institute
IoT	Internet of things
IIoT	Industrial internet of things
IT	Information technology
M2M	Machine-to-machine (networked device communication)
N	Sample size (number of subjects in the study); also used for subsamples, such as the number of subjects with valid data for a specific question
NAICS	North American Industry Classification System (NAICS)
NIST	National Institute of Standards and Technology
NVIE	Nevada Industry Excellence
p	Measure of statistical significance (lower *p* values indicate higher levels of statistical significance)
RFID	Radio frequency identification
RTLS	Real-time locating system
s.d.	Standard deviation, a measure of how much variation the results show around the mean
SM	Smart manufacturing
SMMs	Small and medium manufacturers
VR	Virtual reality

INTRODUCTION

The manufacturing industry in the United States provides an invaluable basis for research, development, innovation, productivity, and job creation: it generates more economic activity than any other sector [9] and has a substantial impact on the overall US economy [10]. Manufacturing is also highly energy intensive [11]. When accounting for both direct emissions from the manufacturing processes and indirect emissions from the associated electricity use, the industrial sector was the largest contributor of greenhouse gases of any sector, with almost 29% in 2018 [12]. This makes the manufacturing sector a prime target to address how energy and process inefficiencies impact productivity, with consequences for companies' economic health and competitiveness, and for the environment [11, 13].

Manufacturing is a fruitful area of focus for improving efficiency and reducing carbon emissions. In 2018, the industrial sector (which includes manufacturing and non-manufacturing industrial uses such as mining, construction, and agriculture) used about one third of the total energy consumed in the United States [14], with most of this energy consumption attributed solely to manufacturing [11]. In the United States, small businesses constitute more than 99% of total businesses employing 47.5% of the workforce [15]. The large share of small and medium-sized enterprises is similar across other regions and nations [16, 17]. Understanding trends in technical readiness and adoption of energy efficient products among small businesses is therefore important to help meet state and federal policy goals towards carbon emissions reduction.

The purpose of this project was to design and administer a survey to small and medium manufacturers (SMMs) in Nevada to assess attitudes, experience, and technical readiness regarding the adoption of smart manufacturing solutions. Respondents were asked about their experiences using specific SM products, and were asked to identify the major drivers and barriers to adoption. Results from this study can be used to characterize the current landscape of smart manufacturing in SMMs, and help policymakers target identified barriers to adoption.

SMMs and Smart Manufacturing

Smart manufacturing (SM), also known as Industry 4.0, emphasizes the use and integration of intelligent machines, real-time data, embedded software and the internet to organize, streamline, and automate operations [16, 18]. The National Institute of Standards and Technology (NIST) defines smart manufacturing systems as "fully-integrated, collaborative manufacturing systems that respond in real time to meet changing demands and conditions in the factory, in the supply network, and in customer needs" [19]. In other words, smart manufacturing is the practice of using information about the manufacturing processes when and where it is needed, and in the form that it is needed, by people and machines [20, 21].

Surveys of SMMs can provide insight into the attitudes and problems surrounding smart technology adoption in these businesses, but more research is needed in this area. Studies by Moeuf, et al. [22] and Nimbalkar, et al. [13] used secondary data to identify which smart manufacturing technologies are utilized by SMMs. A survey of 43 small-to-medium manufacturers in New Zealand showed that almost all companies use Information Technology (IT) services with their accounting and finances (90%) and with procurement and inventory management (83%) [23]. IT technology was used less often for networked control of the production equipment (38%) and for managing or decreasing energy consumption (21%). However, the study did not explore what specific types of IT or other technologies were used by these SMMs. According to a United States market survey with a majority of medium-sized (50 to 250 employees) manufacturers represented in the sample, 77% said that they did not have plans to implement internet of things (IoT) technologies [6]. In this study, addressing workforce challenges, cutting operational costs, and seeking new markets emerged as the top three priorities, while utilizing the industrial internet of things (IIoT) had the lowest priority for these manufacturers. Another survey of 54 West Virginia manufacturers (70% of which were SMMs with up to 499 employees) indicated that only 14% of these manufacturers had adopted smart manufacturing practices in their operations [24].

SMMs and Barriers to Technology Adoption

Relatively little data is available about the perspectives of US SMMs on smart manufacturing. In the US, surveys have been conducted by consulting firms or interest groups, but these focus on larger and already engaged manufacturers [see for example 1, 2-4]; when they include smaller manufacturers, results are rarely presented stratified by enterprise size [see for example 5, 6, 7]. Only a few academic survey studies assessed the status of implementation and uptake of specific technologies and the perspective of SMMs regarding the drivers and barriers of SM in the US. Wuest, et al. [24] surveyed 54 manufacturers, 70% of which were SMMs with up to 499 employees, to give an overview about SM in West Virginia. The results showed that the surveyed manufacturers had little knowledge of SM. While almost 60% said that they had heard the term, there was little understanding of smart manufacturing technologies and applications. From accompanying interviews, the authors concluded that smaller companies have less awareness about this topic and that those companies that are interested in the topic are in the early phases of transitioning to smart manufacturing.

Several barriers hinder SMMs from adopting SM technologies. However, relatively little research exists that fully characterizes the special needs of SMMs A few previous studies provides hints at these challenges. First and foremost, SMMs need to be willing to consider SM technologies for their operation. Thus, a mind-set that does not embrace new technologies acts as a major barrier, as detailed in a survey and interview study in West Virginia [24]. Surveys conducted in Europe [25], New Zealand [23], and South America [26] indicate that another main reason why manufacturers in general and especially SMMs have not taken advantage of smart technology is the substantial amount of financial resources that is necessary to implement cyber-physical systems. Similarly, the West Virginia SM study pointed out that for those manufacturers who have decided to embark on the smart manufacturing journey, the initial cost of these new technologies is the main barrier [24]. Another study surveyed 618 U.S. manufacturers, 78% of whom were SMMs, although their answers were not reported separately [5]. In this survey, the lack of funding was mentioned by 52% of the respondents as a main reason for withholding investments in SM. Also, 36% mentioned an insufficient return on investment.

Another significant barrier is the amount of time it takes to explore and implement smart solutions [23]. Three quarters of all U.S. SMMs employ fewer than 20 people; thus, SMMs may lack the capacity to tackle the process of digitalization of their operations. SMMs often do not employ sufficient personnel with the skills or training needed to use these technologies [23, 24]. The complexity of technology and anticipated technical problems can be off-putting for SMMs that lack specialized personnel to support the implementation and maintenance of smart infrastructure [27]. Indeed, 32% of the respondents in the Advanced Manufacturing Media Survey mentioned a lack of technical skills as a barrier to invest in smart technologies [5].

Given the lack of consistent data available at both state and national levels specific to SMMs, it is difficult to ascertain the prevalence of specific smart technologies currently in use. Lack of data also prevents researchers from understanding and characterizing common drivers and barriers to adoption, and inhibits the ability to identify emerging trends in uptake.

METHODOLOGY

The survey instrument used here was developed by the California Plug Load Research Center at the University of California, Irvine (CalPlug), based on one the team designed and implemented for an analogous project funded by the U.S. Department of Energy through CESMII (Clean Energy, Smart Manufacturing, Innovation Institute) [8]. That study targeted SMMs across the U.S., but provided limited data on any one state other than California. The original questions were based on an extensive review of prior studies. The team consulted with experts to construct a list of twenty specific SM technologies and designed questions to assess how they have been used or could be used in SMMs. For the current study, some questions and items were omitted to reduce length, while new questions added; those that remained retained the same wording (and scale construction) to facilitate comparability across the two surveys. Topics focused on: 1) level of preparedness for adopting new technologies, 2) experiences with smart technologies currently or previously used in their facilities, and 3) drivers and barriers to new technology adoption. All questions allow for "don't know" and "prefer not to answer" responses to avoid forcing uninformed guesses.

The survey was administered online, using Qualtrics survey software. Data collection was open from October 2021 to January 2022. Subjects were recruited by email, starting with Nevada Industry Excellence's (NVIE) contact list of Nevada SMMs, and updated to replace outdated contacts whenever possible. Announcements were included on the NVIE website and newsletters. Recruitment materials clarified that the survey should be filled out by only one person per company, and responses were tracked using individualized survey links. As an incentive, subjects were offered the chance to enter a lottery in which three randomly selected winners would be offered their choice of three prizes (an Apple iPad 9th Generation (value approx. $480), an Apple Watch Series 7 (value approx. $400), or an Oculus Quest VR headset (value approx. $400)) along with a one-hour consultation with an NVIE expert on how to advance smart manufacturing in their company. Subjects were deemed eligible if they were 18 or older and owned or worked for a Nevada SMM (i.e., independently operated manufacturers with fewer than 500 employees within Nevada). Over 1800 emails were sent, of which 3% were duplicates, 4% were invalid, and 86% received no response; assuming all unanswered emails were accurate and delivered, the refusal rate is calculated at 2% and the response rate at 5%. Statistical analyses were conducted using SAS 9.4. For the purposes of these analyses, any p level less than .05 is considered significant; however, given the modest sample size, weak or "trend-level" significance levels of $p < .10$ are also reported.

RESULTS

Subject Characteristics

A total of 84 valid subjects representing Nevada small and medium manufacturers (SMMs) completed the survey. The majority were coded as upper level status, including 40% owners and 33% in upper management (e.g., president, VP, CEO). Subjects are grouped into midlevel status if they identified as a middle manager (14%), technical expert (6%), or operations manager (6%). Consistent with the focus on upper management, subject ages are higher than the typical labor force, with 21% 65 or older, 30% 55 to 64, 27% 45 to 54 and most of the remainder 35 or younger. The sizes of the SMMs are shown in Table 1. For analyses, these categories are frequently combined into three groups, as shown, or one group is compared against the others.

Table 1. Number of Employees

	Number	Percent	Grouped
1 to 4	5	6%	40%
5 to 19	29	35%	
20 to 49	25	30%	30%
50 to 99	12	14%	30%
100 to 499	13	15%	

Industry type categories were drawn from the North American Industry Classification System (NAICS) [28]. The Nevada SMMs represented by the subjects in this study's sample vary widely across these types. Due to the relatively small numbers in most industry codes, they have been grouped into categories for assessment. These categories are shown in Table 2; within each category, the subtypes are sorted by level of representation (with larger groups first). NAICS categories with zero subjects are omitted.

Table 2. Distribution of Industries in this Study

Industry Category and Subtypes	Number	Percent
Metals and Machinery	26	31%
Fabricated metal product manufacturing		
Primary metal manufacturing		
Machinery manufacturing		
Transportation equipment manufacturing		
Electronics	18	21%
Electrical equipment, appliance, and component manufacturing		
Computer and electronic product manufacturing		
Food and Beverage	14	17%
Food manufacturing		
Beverage and tobacco product manufacturing		
Plastics/Chemicals	14	17%
Plastics and rubber products manufacturing		

Chemical manufacturing		
Wood and Textiles	12	14%
Wood product manufacturing		
Printing and related support activities		
Textile product mills		
Apparel manufacturing		
Leather and allied product manufacturing		

Most commercial activity in Nevada is centered around two population hubs, anchored by Las Vegas in the south and Reno in the north. The geographical distribution of the manufacturing companies represented in this study follows this pattern, with 60% of subjects near the Reno/Sparks and Carson City areas and 40% in and around Las Vegas (see Figure 1).

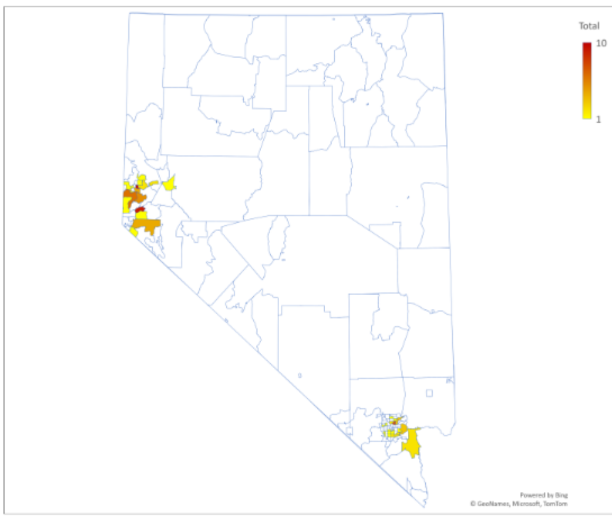

Figure 1. Geographical Distribution of Nevada SSMs in this Study

Readiness to Implement Smart Manufacturing

A major question in this study, as with other studies of SMMs, is how ready companies in Nevada are to adopt smart manufacturing strategies. One measure of readiness level is whether a company has already implemented new technologies, or how prepared they are to do so (see Figure 2). About one in four companies have at least started implementing smart manufacturing, although most are at an early stage. Another 30 percent have developed some plans for implementation, while fully one in four report being not prepared. It is also striking how many subjects were unable to answer this question; “don’t know” and “no answer” responses were significantly more common among mid-level employees than top management (32% v. 11%, p = .0264), suggesting that the subject has not been widely discussed in their companies.

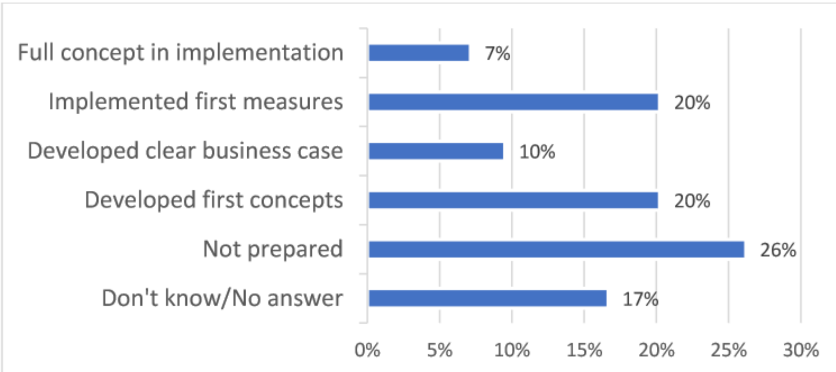

Figure 2. Implementation Level

Another measure of readiness uses seven items based on the Industry 4.0 Readiness Index [29] (see Table 3). The question used a five-level Likert scale from strongly agree to strongly disagree (coded so that a higher score indicates higher agreement). Results show a mean of 3.6 (s.d., 0.7), midway between the neutral middle response and "somewhat agree." This level of perceived readiness is higher than the scale mean of 2.95 (s.d., 0.7) reported in the study the question was based on [29]. Owners and top management subjects report a significantly higher average level of readiness than midlevel employees ($p = .0200$); this is largely driven by these subjects being significantly more likely to rate management (that is, themselves) as being willing to take risks to experiment ($p = .0015$) and as supporting the company ($p = .0027$). Upper management is also more likely to say that employees have the right motivation, although this is only weakly significant ($p = .0605$). The readiness index is not correlated to company size or industry type.

Table 3. Readiness Index

	Overall			Upper level			Middle level			
	N	Mean	s.d.	N	Mean	s.d.	N	Mean	s.d.	sig.
Readiness Index	80	3.6	(0.7)	59	3.7	(0.6)	21	3.3	(0.9)	*
Management pressured to work with SM	79	2.9	(1.2)	59	2.9	(1.3)	20	3.0	(1.2)	
Management willing to take risks to experiment	79	4.0	(1.0)	59	4.2	(0.8)	20	3.4	(1.2)	**
Management has nec knowledge about SM	82	3.7	(1.2)	61	3.7	(1.2)	21	3.6	(1.1)	
Company has support from top mgt	80	4.1	(0.9)	60	4.3	(0.8)	20	3.6	(1.1)	**
Employees have right competencies	80	3.4	(1.2)	59	3.5	(1.1)	21	3.0	(1.5)	
Employees have right motivation	79	3.6	(1.1)	58	3.7	(1.0)	21	3.2	(1.2)	^
Company has economic freedom	79	3.4	(1.2)	60	3.5	(1.2)	19	3.1	(1.3)	

Significance level: ** $p < .01$, * $p < .05$, ^ $p < .10$

A key concern about adopting new technology is whether the existing employees have sufficient skills to adapt to SM. As shown in Figure 3, fewer than one in five subjects believe their company's existing employees have the skills needed to adapt to SM technology. The majority (62%) think their company's workers could adapt with more training, but a substantial minority (17%) believe the company would need to hire new workers. No significant relationships were found between this variable and the company size, industry type, or status level of subject, suggesting that this level of workforce training needs may be fairly consistent across Nevada SMMs.

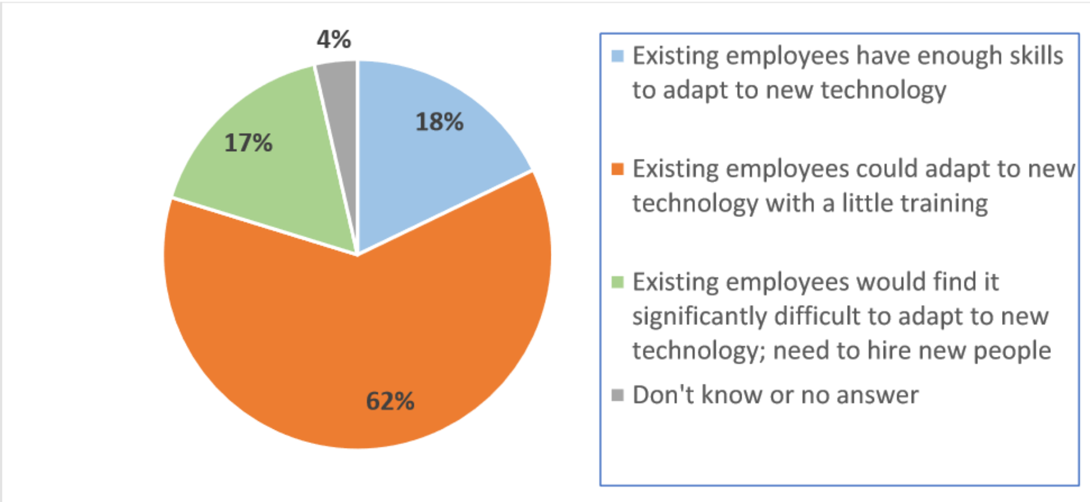

Figure 3. Training and Hiring Needs

Subjects who reported that current employees would need more training or to be replaced were asked two additional follow-up questions: what percent of current employees would need additional training and what percent that would need to be replaced with new hires. [1 2] All subjects who gave valid answers to the training and hiring needs question were asked how many additional employees would need to be hired to implement smart manufacturing, if any.[3] As shown in Table 4, on average, subjects reported that 49% of their existing employees would need additional training to adapt to smart manufacturing and 14% would need to be replaced with more skilled workers. In addition to any hires needed to replace workers, subjects estimate they would need to increase their current workforce by an average of 8% by hiring additional, more skilled employees.

[1] These two questions were not asked of those who reported in the prior question that existing employees have enough skills to adapt, and are automatically coded zero for those subjects.
[2] Many subjects are not reflected in the valid subsamples for these items because they selected "don't know" or "prefer not to answer" for the initial training needs question or the follow-up question. Also, a survey program glitch allowed subjects to click past the follow-up questions without entering a percent response; these are treated as "prefer not to answer" and omitted.
[3] The question reads, "How many new employees would your company need to hire to adapt to smart manufacturing, if any, compared to your current number? For instance, if your company has 50 employees and would need to hire 5 more, put 10%." For subjects who had just been asked, "What percentage of employees would need to be replaced with more skilled workers?" this clarification was added: "Don't include new hires needed for any replacements mentioned above."

Table 4. Average Percent of Employees Affected by Training and Staffing Needs

	N	Average	s.d.	Min	Max
Percent that would need more training	80	49%	(.34)	0	100
Percent that would need to be replaced	71	14%	(.17)	0	75
Percent additional new hires needed	66	8%	(.09)	0	33

While the average percent of employees that would need more training is 49%, responses range from a minimum of zero to a maximum response of 100% of the current workforce. The ranges are relatively large for the other two questions as well, and the standard deviations are relatively large compared to the averages. This indicates great variation across responses, meaning the average results are not telling the whole story.

To explore this further, the percentages subjects gave for how many employees would be affected were grouped into categories: zero, 1 to 24%, 25 to 49%, 50 to 74%, and 75% or more. Figure 4 shows the percent of subjects whose reports fell into each category. Only 20% of subjects said that none of their company's employees would require more training. Three of every four companies (74%) would need additional training for at least 25% of their employees, including 33% who would need to train at least 75% of their current workforce. The majority of companies (62%) would need to replace at least some employees who could not be effectively trained, with one in five (22%) needing to replace 25% or more of their current workers. Even more of a concern, the majority of companies (73%) would need to hire additional workers (in addition to any replacements) to meet the needs of smart manufacturing. Although the numbers are smaller than for the other staffing needs—with most less than 25%--increasing staff levels is even more costly and difficult than replacing existing workers. For a closer look at hiring needs, subjects were divided into more detailed categories at the lower end of the percentage scale than are shown on this figure: these results indicate that 30% of companies need to add another 1 to 9% of workers to their workforce, 24% need 10 to 19% more, and 18% need 20 to 33% more.

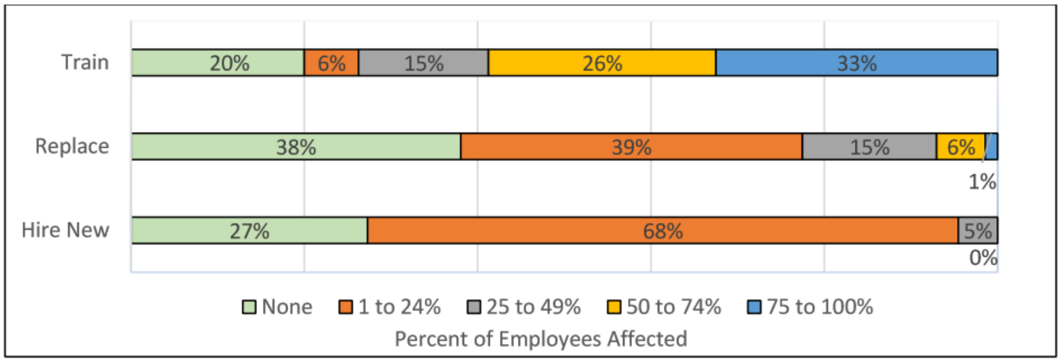

Figure 4. Reported Staffing and Training Needs

The three types of staffing needs are all positively correlated to one another. That is, subjects who report higher needs for training also report higher needs for replacing staff (r = .488, p < .0001) and

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higher needs for expanding with new hires (r = .308, p = .0119). Similarly, those who need to replace existing staff are likely to need additional new hires as well (r = .344, p = .0062).

The percent of workers that would need to be replaced is somewhat lower for the smallest companies (fewer than 20 employees) than for larger ones, at 17% versus 10%; however, this difference is significant only at the trend level (p = .0631) and does not persist across other ways of categorizing companies by size, so it is not robust. As with the earlier workforce needs categorical question, the workforce needs percentage measures do not differ across industry types or by employee status of the respondent: in other words, results are similar across groups among these SMMs.

Drivers and Barriers

Problems that Smart Manufacturing Could Solve

One measure of drivers is the extent to which companies have sufficient incentive to upgrade to smart technologies. Lower-tech approaches can be effective for certain tasks or processes, especially at the smaller scale of SMMs. If companies are not experiencing productivity problems that would be noticeably improved by new technology, the investment of time and money would not be worth it.

The question wording is: "In some situations, it's easier to use traditional, lower-tech solutions, such as paperwork on clipboards, or manually checking readouts to make decisions. In other situations, these solutions are slow or unwieldy compared to newer technologies. Do you think your company would benefit from adopting smart manufacturing solutions for any of the following tasks?" A list of nine tasks followed. Findings are shown in Figure 5, with tasks sorted by the percent of subjects who reported that lower-tech solutions work fine. The tasks at the top of the figure---managing stock, analyzing data, completing timesheets, and inputting data into forms—are the least likely to be seen as preferable to do with lower-tech solutions (13% to 17%) and the most likely to either be currently using smart solutions or that would benefit from doing so (combined, 71% to 73%). The highest rate of already using smart solutions is given for completing timesheets (37%); for other tasks, rates of current use show a fairly narrow range of 18% to 25%. At the bottom of the figure, assigning jobs or tasks and internal communication were most often rated as easier to do with low-tech methods, although even here, one in three subjects says those tasks could benefit from smart solutions.

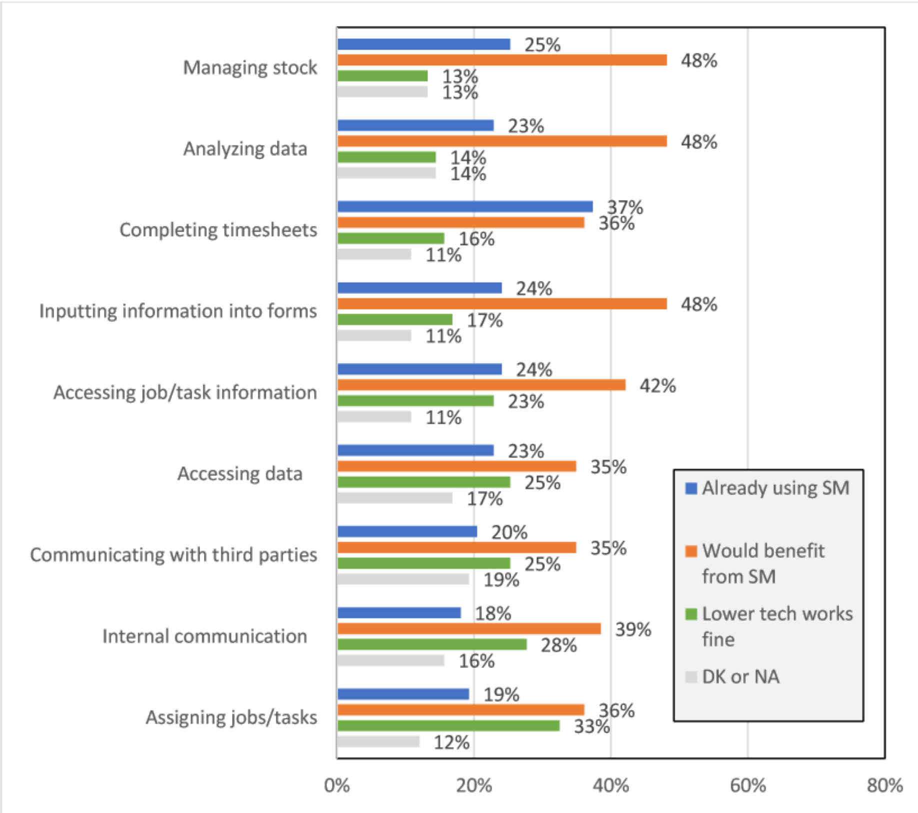

Figure 5. Tasks that Could Benefit from Smart Manufacturing

Perceived Drivers and Barriers

An important driver for adopting SM is the perceived benefits. Subjects were offered ten potential drivers and a write-in "other" category and asked what they saw as the most critical factors driving their company to implement smart technologies. Barriers to adopting smart manufacturing are also influenced by perceptions of anticipated problems, such as the difficulty or costs of the solution. Subjects were offered eleven potential barriers and asked what they saw as the most critical barriers to implementing SM for their company or for the SMMs they consulted with. For both questions, subjects were allowed to select up to three, and could write their own answers into an "other" category. Subjects who chose more than one item were then asked to narrow down the top-most factor. As shown in Table 5, five subjects perceived no drivers—that is, none of these factors motivated their company toward adopting more smart manufacturing solutions, and they offered no "other" write-in factor that would. Two other subjects perceived no barriers; no subjects reported none for both questions.

The majority reported at least one driver and at least one barrier, with many reporting the maximum of three.

Table 5. Number of Drivers and Barriers Selected

	Drivers		Barriers	
None	5	6%	2	2%
1	18	21%	17	20%
2	20	24%	13	15%
3	35	42%	46	55%
Don't know/no answer	6	7%	6	7%

Results for the drivers and barriers selected are shown in Figure 6 and Figure 7, sorted by those cited by the most subjects.[4] The first (blue) bars show the percent of subjects who chose the item as one of their top three, while the second (orange) bars show how many chose it as the "topmost" driver or barrier.

By far the most frequently cited of these drivers for was to reduce costs, listed in the top 3 by 68% of subjects and as the topmost driver by 36%. The next highest driver was to improve time-to-market, mentioned in the top 3 by 38% and as the topmost driver by 13%. For barriers, costs were again cited by the largest proportion of subjects, at just over half (53%). Almost one in three mentioned the next three barriers: uncertainty about the effects of the investment on profits, investment of time, and lack of qualified employees. When forced to choose one topmost barrier, costs and profits were deemed more important than time and staffing concerns by more subjects.

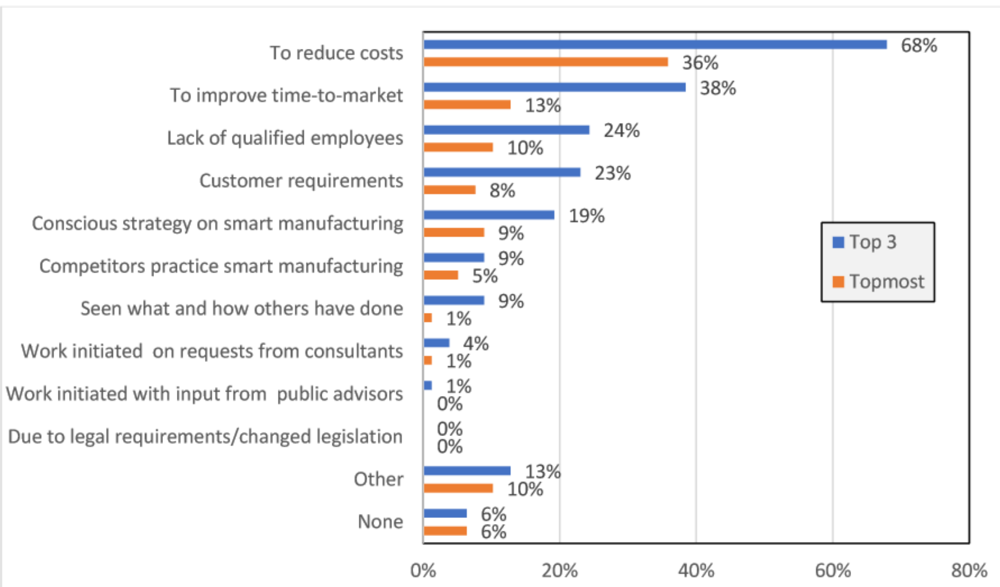

Figure 6. Perceived Drivers to Adopting Smart Manufacturing

[4] As the figures omit the don't know and no answer subjects when calculating the percentages, the percent of "none" answers is slightly different from the previous table.

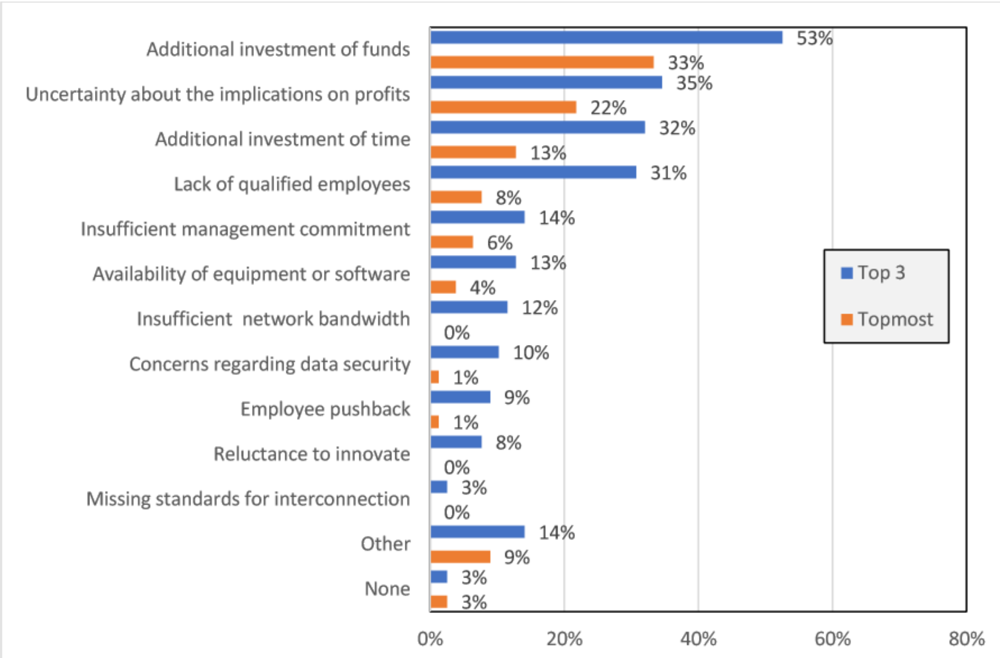

Figure 7. Perceived Barriers for Adopting Smart Manufacturing

Specific Smart Manufacturing Technology Types

One of the main purposes of this study was to determine which specific SM solutions SMMs in Nevada already had deployed, and what the reaction to these had been, as well as which ones they had tried or considered and decided against.

Currently Used Technologies

The survey offered a choice of twenty technologies and asked subjects which of them were being used in their companies "as part of a smart manufacturing solution." Subjects reported using an average of 4.7 smart technology types in their companies. As shown in Figure 8, about half the companies use fewer than 5 of these 20 technologies, including 7% who use none. Most of the rest use five to eight, with a small proportion using more than that, and only two reporting the maximum observed here, 13.

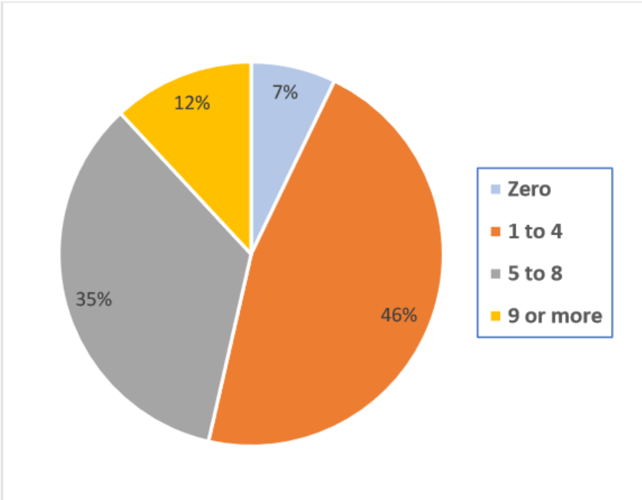

Figure 8. Number of SM Technologies Used

Within the SMM size range, smaller companies use significantly fewer types of these technologies, as shown in Figure 9 (p = .0186). This is mostly driven by the difference between those with fewer than 20 employees compared to those with 20 to 499 employees (average 5.4, p = .0080). The number of technologies used is not statistically related to the industry type or to the subject's status level.

Figure 9. Average Number of SM Technologies Used, by Company Size

Subjects who reported that a given technology type was not currently used were asked whether that technology had ever been implemented but was later discontinued due to problems with it, or if the company had seriously considered implementing the technology but decided against it based on expected problems. The combined results of these two questions are shown in

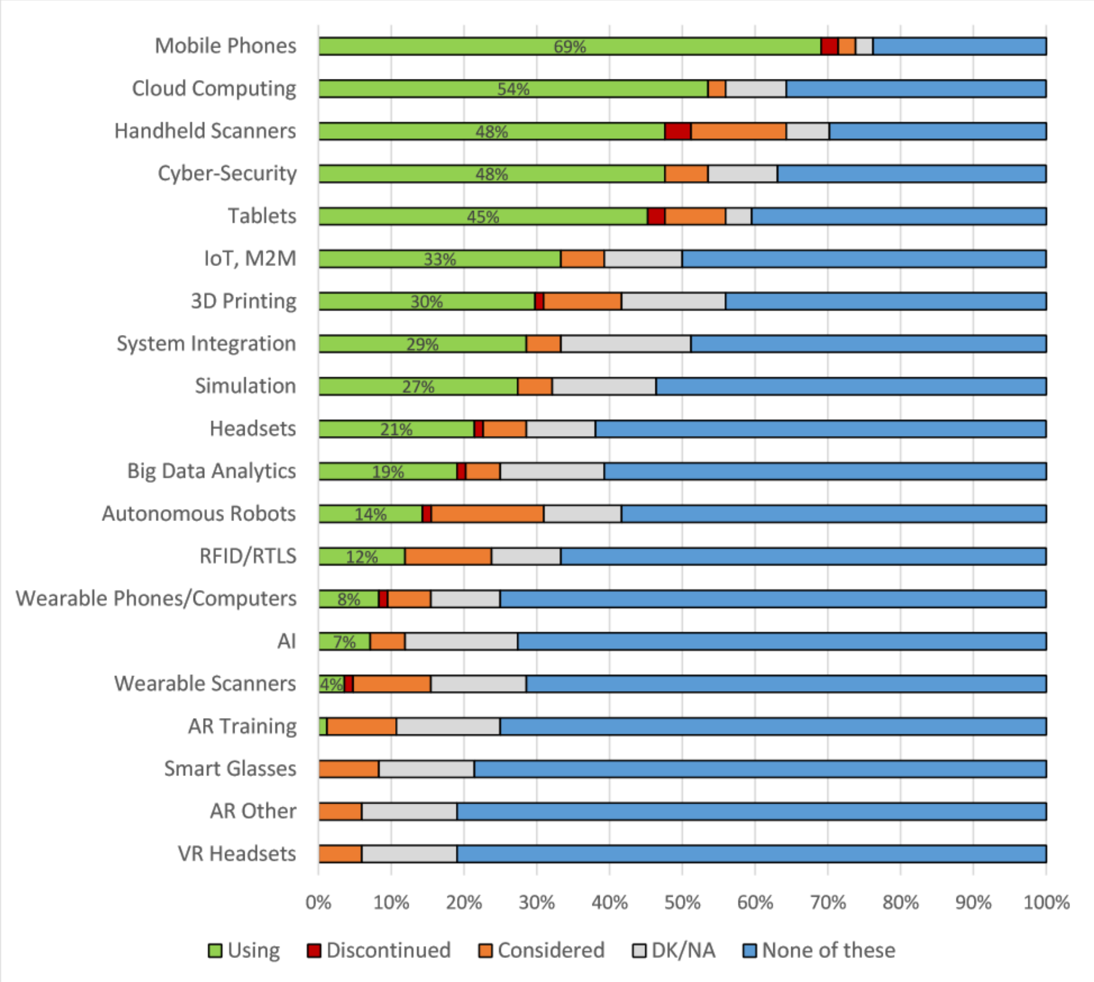

Figure 10, sorted by the percent of subjects whose companies are currently using the device. The primary take-away is identifying which types of technologies are most commonly used: mobile phones are by far the most used (69%), followed by cloud computing (54%), handheld scanners (48%), cyber-security (48%), and tablets (45%). By contrast, no subjects report using VR headsets, AR for reasons other than training, or smart glasses, and fewer than one in ten report using AR for training, wearable scanners, artificial intelligence (AI), or wearable computers. These technologies also have the highest rates of “none of these", where subjects said "no" to current use, used but discontinued, and considered but rejected.[5] In other words, these technologies have never even been considered by these SMMs, despite being in the top twenty solutions (as used by larger manufacturers) promoted by the literature and the SM experts consulted for the original study. Only a handful of subjects reported that their companies implemented any technologies and later discontinued them. However, many technologies have previously been considered and rejected (thus far) by at least one in ten of these companies, specifically: autonomous robots, handheld scanners, wearable scanners, AR for training, radio frequency identification and real-time locating systems (RFID/RTLS), and 3D printing.

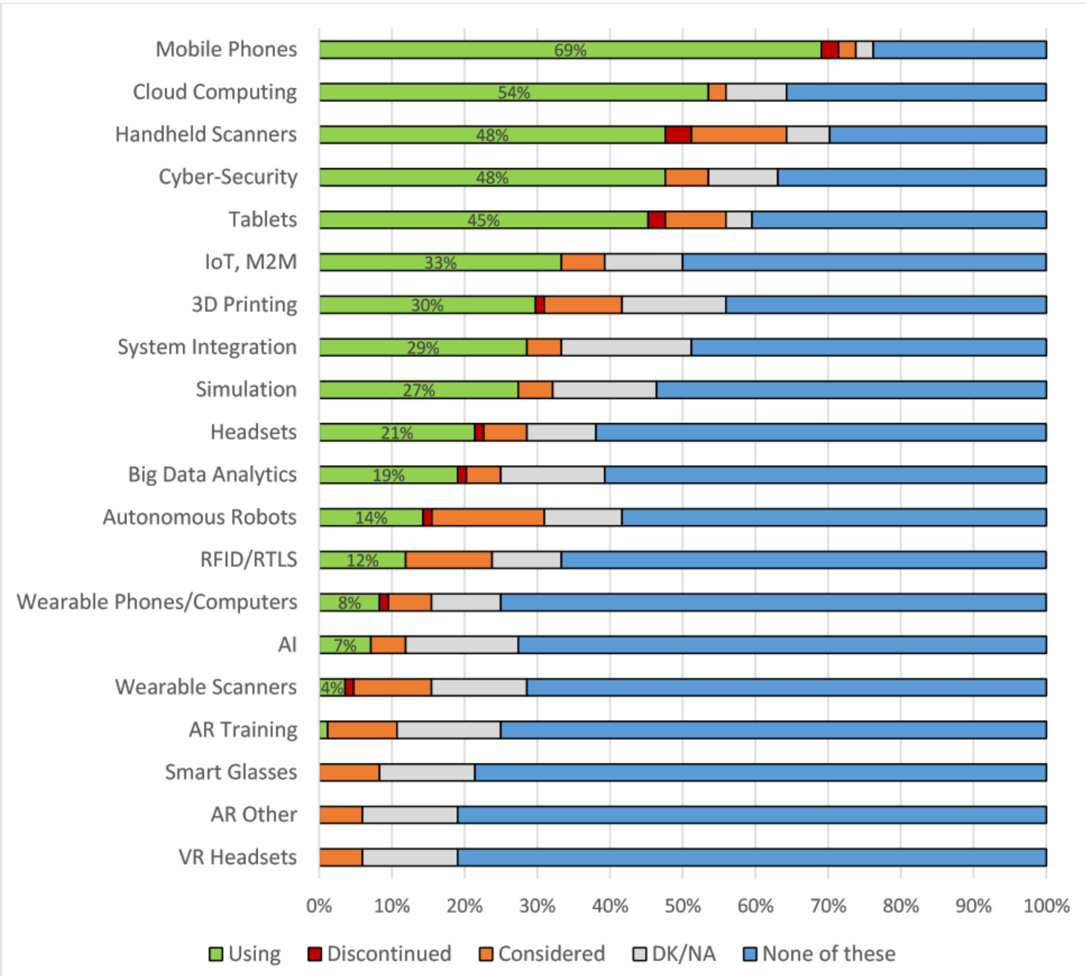

Figure 10. Current Use, Past Use, and Consideration of SM Technologies

[5] Note that the "none of these" category does not include subjects who selected "don't know" or "prefer to answer" for those questions, only those who said "no".

There are some differences across industry categories in the number of SM technologies used, as shown in Figure 11. The food and beverages and metals groups are tied for the highest number in use, with an average of 5.3 technologies, followed by wood and textiles with 4.8 and electronics with 4.4. Plastics and chemicals has the lowest average technology use, at 3.3 types; when comparing this group against all others, the difference approaches significance at the trend level (p = .0626).

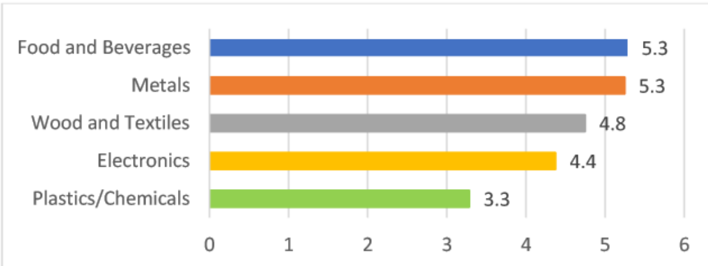

Figure 11. Average Number of SM Technologies Used, by Industry

The industry groups also exhibit some differences in which of the SM technologies they use. Industry averages for the top ten SM technologies are shown in Figure 12. The industry types are sorted by the average number of SM technology types used; if the technologies were evenly distributed across industries, the bars in Figure 12 would follow the same pattern as Figure 11. For many of these technologies, they do, with the highest usage among the industry groups with higher overall usage Differences across all five industry groups are statistically significant for three technology types: cybersecurity, IoT, and 3D printing. 3D printing is especially interesting, as it is much less often used in the food and beverage SMMs than other technologies, while being used much more by electronics and appliance manufacturers than for other industry types. For other technologies, the patterns are suggestive, but not strong. With mixed results of this type, it could be that there are actually no strong differences across industry types for Nevada SMMs. But it is also possible that the differences are real and the sample size for this study is not large enough to show them, in which case follow-up research with additional companies would produce more robust results.

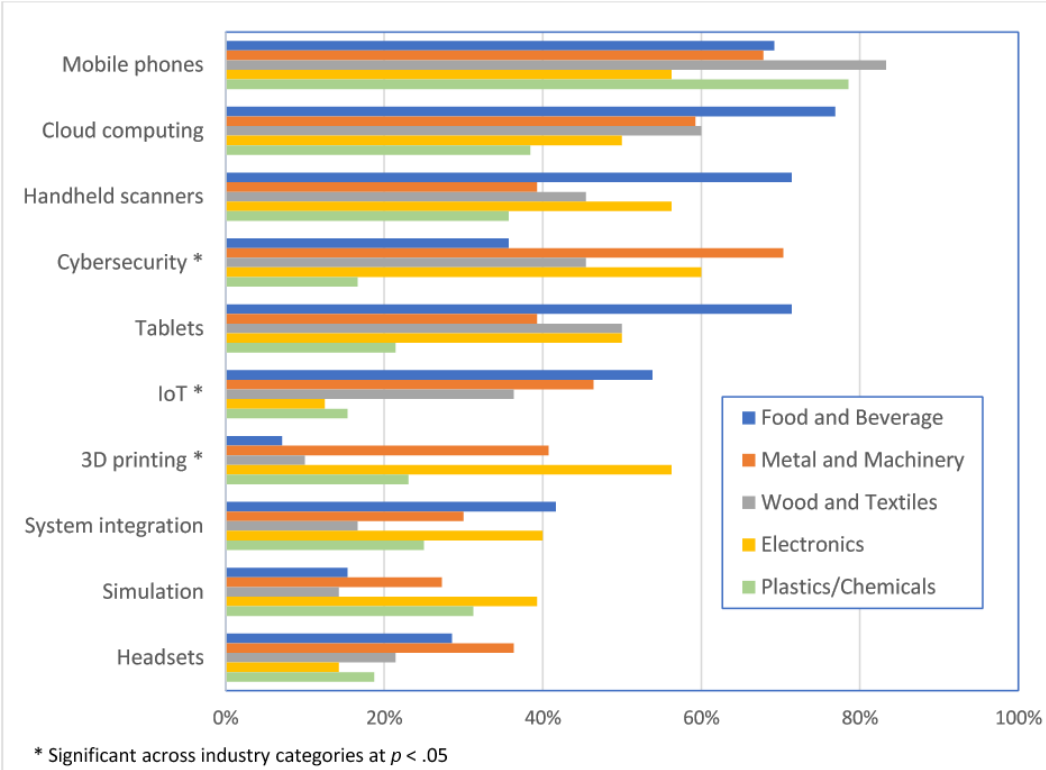

Figure 12. SM Technologies Used, by Industry Group

Evaluation of Smart Technologies Used

Subjects who reported that their companies had implemented specific new technologies were asked how satisfied they were with the technology on a five-point scale from very satisfied to very dissatisfied. These subjects were also asked, "how did most workers in your company react to implementing" each type of technology, on a five-point scale from strongly positive to strongly negative. It is important to remember that this question captures the subject's *perceptions* of how workers reacted rather than a direct measure from the workers themselves. Technologies used by fewer than ten companies are removed from these analyses; both measures are coded so that higher numbers mean more positive response.

Average evaluations for individual SM technologies are shown in Table 6, which includes only those technologies with at least ten responses and is sorted by average subject satisfaction. Note that averages across subjects tend to be more reliable with larger sample sizes, so results should be treated cautiously, especially for those technologies used by fewer companies in this sample. Across all technologies used, reactions are reasonably good, with an average subject satisfaction of 4.0 (corresponding to "somewhat satisfied" on the response scale) and an average worker reaction of 4.1 (corresponding to "somewhat positive"). Overall response to using smart technologies, whether for subjects or workers overall, does not differ by number of technologies used, company size, industry category, or subject status level. This is somewhat reassuring, as more positive perceptions of worker response for medium-sized versus small companies or for upper management might have implied that those subjects were out of touch with their workers' negative reactions.

Table 6. Evaluation of SM Technologies Used

	Subject Satisfaction			Worker Response		
	N	Mean	s.d.	N	Mean	s.d.
Average for all 20	60	4.0	(1.1)	56	4.1	(0.6)
Autonomous Robots	12	4.3	(1.0)	12	4.3	(1.2)
Big Data Analytics	16	4.3	(0.8)	15	4.3	(0.8)
3D Printing	24	4.3	(1.2)	25	4.5	(0.7)
Cloud Computing	43	4.2	(1.1)	41	4.2	(0.9)
Mobile Phones	57	4.1	(1.3)	54	4.4	(0.7)
Cyber-Security	38	4.1	(1.2)	34	3.9	(0.9)
IoT, M2M	27	4.0	(1.2)	25	4.2	(0.8)
Tablets	37	3.9	(1.4)	37	4.2	(0.7)
Simulation	23	3.9	(1.3)	22	4.2	(0.8)
System Integration	24	3.8	(1.1)	23	4.0	(0.8)
Headsets	17	3.8	(1.0)	16	3.9	(1.2)
Handheld Scanners	37	3.5	(1.4)	38	4.0	(0.9)

Although average evaluations appear fairly positive across most technologies, averages can mask variation: the same technology can lead to very positive evaluations in some companies and less positive ones in others. A substantial percent of subjects were not satisfied (that is, neutral or dissatisfied) and/or reported that workers did not have positive reactions (that is, neutral or negative). These findings are shown in Figure 13 for the SM technologies with at least ten responses each. By design, these results generally track the averages shown in Table 6, but provide an alternate view of the problem. For example, average subject satisfaction is the same for tablets and simulation at 3.9 and only 0.1 lower for system integration; while this is lower than many other technologies on this list, the substantive interpretations are not immediately clear. Examining the percent with non-positive responses shows that 27% of these subjects were not satisfied with tablets versus 35% who were not satisfied with simulation, whereas only 21% were not satisfied with system integration. Similarly, while it is useful to know that cyber-security and headsets both received the lowest average rating for worker positive response, it may be more actionable to learn that 35% of workers had neutral or negative reactions to implementing cyber-security, as did 31% for headsets and 35% for system integration.

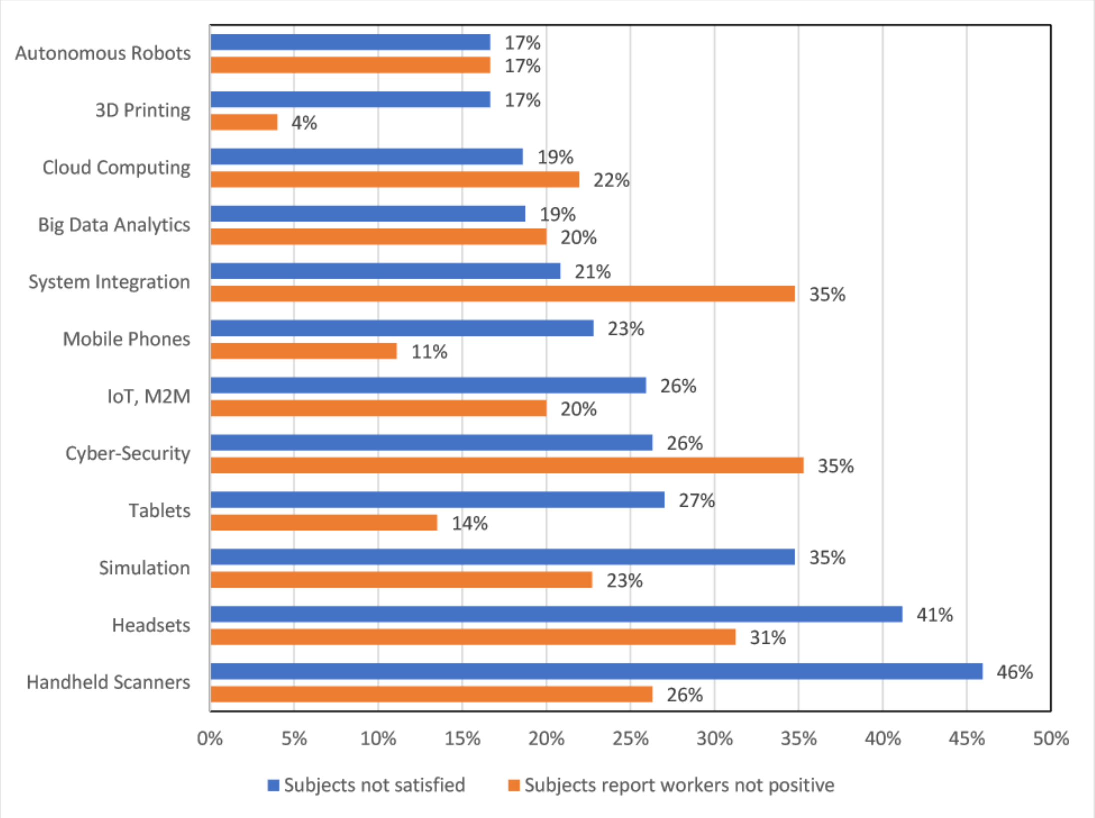

Figure 13. Percent Reporting Neutral or Negative Responses to SM Technologies Used

Relationships Between Readiness, Technology Use, and Staffing Needs

Earlier sections covered the descriptive results for each of the key measures and whether they differed by company size, industry type, or subject's status in the company. Now that all the measures have been discussed, we turn to relationships between them.

In theory, different readiness measures should be positively correlated with each other, and also with reported use of SM technologies. As a lack of correlation could indicate problems with the survey or measure—for instance, that subjects hold inconsistent perceptions or definitions of readiness—it is reassuring that these correlations are found here, even with such a modest sample size (see Table 7). Among these Nevada SMMs, those who report having implemented at least the first measures of an SM solution have significantly higher scores on the readiness scale than those who have not started implementing (mean 4.0 v. 3.4, $p = .0018$). Subjects who report implementing at least the first measures also report using significantly more SM technologies than those with lower levels of preparation (mean 6.2 v. 4.2, $p = .0114$). The number of SM technologies these companies are currently using is also positively correlated to the readiness index ($r = .520$, $p < .0001$).

Table 7. Correlations Between Readiness, SM Technology Use, and Staffing Needs

	Readiness	Need training	Need to Replace	Need to Hire	Number types	Subject Satisfact.	Worker Reaction
Readiness scale	---						
Percent of employees need training	-.272 *	---					
Percent of employees need to be replaced	-.266 *	.488 ***	---				
Percent of new employees need to hire	-.042	.308 *	.344 **	---			
Number of SM technology types used	.520 ***	-.062	-.108	.118	---		
Subject satisfaction with SM types used	.204	-.160	-.140	-.034	.170	---	
Worker reaction to SM types used	.447 ***	-.250 ^	-.412 **	-.125	.081	.277 *	---

The *r* statistics shown reflect the direction and size of the relationship between the two variables. Zero means no relationship, +1.0 means a perfectly positive correlation and -1.0 means a perfectly negative correlation; that is, values farther away from zero indicate stronger relationships.

Significance level: *** $p < .001$, ** $p < .01$, * $p < .05$, ^ $p < .10$

Subject and worker evaluations of specific SM technologies are expected to be positively correlated to each other: if workers responded well to a technology, this presumably improves the subject's evaluation of how well it functioned, while subjects should have more negative evaluations if workers responded negatively. Indeed, these two measures are positively correlated, although the relationship is only moderate in effect ($r = .28$, $p = .0388$). Perceived worker response to technologies is also strongly positively correlated to the management readiness index ($r = .45$, $p = .0006$).

The questions about subject and worker reactions refer to SM technologies that have already been implemented, whereas the workforce training questions refer to hypothetical adoption of (additional) SM technologies in the future. As such, there is no single logical connection between them: the two may be linked for some companies and separate for others depending on a range of prior experiences and future plans for SM adoption. In the current sample, subjects' satisfaction with the specific SM technologies they've already implemented is not correlated to their assessment of how many workers would need to be trained, replaced, or hired to adopt more SM technology. However, perceived worker response to current SM technology is strongly negatively correlated to the percent of workers subjects estimate would need to be replaced due to insufficient skills ($r = -.41$, $p = .0024$), and weakly negatively correlated to the percent that would need more training ($r = -.25$, $p = .0666$). This suggests a pattern where if adoption of initial SM technology worked out well for the current workers then it bodes well for their ability to handle additional SM adoption, whereas if workers reacted poorly to past SM adoption then more training and new staff will be needed in later rounds of SM adoption.

CONCLUSIONS

The results presented here build upon studies conducted in other states, as well as add insights into new questions and a new focus on Nevada. Although the sample size is modest, it is still the largest quantitative survey of small and medium manufacturers (SMMs) ever conducted in Nevada. It thus helps to quantify previously anecdotal knowledge and apply it to the state context.

The study offers multiple measures of how ready Nevada SMMs are to adopt smart manufacturing and how much they have already implemented. A standardized readiness scale asked seven questions about management and employee attitudes and competencies toward smart manufacturing. The results are cautiously optimistic, with subjects scoring 3.6 on average (from a possible range of 1 to 5). Since a score of 3 means "neither agree nor disagree" this leans toward "somewhat agreeing" that their company is ready, which is better than disagreeing, but not a strong endorsement. Owners and upper level managers reported a significantly higher level of readiness than midlevel managers and technical experts; this difference was largely due to their more positive rating of support and willingness to take risks on the part of top management (that is, themselves). When it comes to actual adoption of smart manufacturing solutions, very few subjects report that their companies have fully implemented SM (7%). However, another 20% have implemented first measures, and another 30% of companies are developing plans. Together, these readiness measures reveal interest among Nevada SMMs for moving forward with SM solutions, but suggest that their ability to fully adopt lags behind their willingness to consider it.

One key factor in readiness to adopt SM is the skill level of the current employees. Employees need specialized skills not only to use the new tools and applications, but to build and maintain the infrastructure to support those tools, and to integrate them into the manufacturing process and decision-making system. In this sample, only 18% of subjects believe their current employees have sufficient skills to adapt to new SM technology. The majority (62%) believe that current employees could adapt if they had additional training (although this includes cases where some employees would need to be replaced), while a substantial minority (17%) believe that current employees would find it difficult to adapt to new technology and new workers would need to be hired. When asked what percent of their workforce would be affected, the answers were sobering. On average, half of employees would need more training (49%); in 33% of these companies, training would be needed for at least 75% of employees. The majority of companies (62%) would need to replace at least some employees who could not be effectively trained, with 22% needing to replace 25% or more of their current workers. Even more of a concern, 73% of these SMMs would need to hire additional workers (in addition to any replacements) to meet the needs of smart manufacturing. New hires that increase total staff levels is even more costly and difficult than replacing existing workers, so even small numbers in this category can act as a major barrier. To adopt SM, 30% of these SMMs need to add another 1 to 9% of workers to their workforce, 24% need 10 to 19% more, and 18% need 20 to 33% more. The three types of staffing needs are significantly correlated: companies that need to train more employees to adapt to SM are more likely to need to replace more and hire more new employees. These results indicate that Nevada SMMs would require substantial levels of training and hiring to adopt to smart manufacturing solutions. Such staffing needs are especially problematic in smaller companies, which have fewer resources and less flexibility for training current employees, or even more costly, hiring and training new workers. Furthermore, even when companies can hire employees with higher baseline skills, those new hires would still require substantial training on the particular equipment and processes. The costs in time and resources are daunting, and help quantify the challenges faced by these SMMs, and the types of support that would be most useful to them as they face this transition.

This study goes beyond general readiness level measures and gives insight into how SM might be applied to improve nine specific work tasks. Depending on the task, between 18% and 37% of subjects reported their companies as already using high-tech solutions, with the most common being completing timesheets. For all nine tasks, the majority of subjects felt that smart manufacturing was either already helping or would be a benefit. However, a substantial minority of subjects reported being satisfied with how well low-tech solutions worked, particularly for assigning jobs or tasks (33%), internal communication (28%), and communicating with third parties (25%). This finding provides an important reminder that not all solutions should be sought simply because they are new and technologically sophisticated. Nevada SMMs need to concentrate their relatively limited resources on adopting only those solutions that solve their specific needs. These results support the adage: don't waste time and money fixing what isn't broken.

One way of understanding both how smart manufacturing can benefit SMMs and also why adoption rates are low is to study drivers and barriers to SM. Among these Nevada SMMs, only five subjects reported no drivers at all—nothing motivated them to adopt SM technologies—while only two subjects reported no barriers. Most subjects endorsed two or three each, and were then asked to narrow down the top-most for each category. The driver most often cited for adopting smart manufacturing was reducing costs—mentioned by two-thirds of subjects and reported as the top-most driver by over one in three (36%). Improving time-to-market was next for top-three mentions, at 38%, but is reported as a top-most driver only by 13%. The corollary is that the topmost perceived barriers to adopting SM were the additional investment of money (33%), uncertainty about the effects on profits (22%), and time (13%). Put together, these findings illustrate the essential challenge faced by many SMMs: they don't have the money needed to invest in order to save more money, and although they'd like to improve their time-to-market, they aren't confident about getting sufficient returns on their investment in SM. This study thus provides quantitative evidence of what SMMs need that many in the field have seen anecdotally. Namely, that lending support to SMMs at these early stages can help pull them out of this cycle; financing assistance and better information on how to achieve solid returns on their investment and measure their results may serve as useful tools to advance adoption.

The study makes another key contribution by addressing experiences with and attitudes toward twenty major smart manufacturing technology types that SMMs might use. Only 7% of subjects reported that none of these technologies were currently used in their companies "as part of a smart manufacturing solution." Almost half of these companies (46%) use one to four of them, with 35% using five to eight and 12% using nine or more. Larger companies in this group (50 to 499 employees) reported using significantly more technology types than the smallest companies (fewer than 20 employees), averaging 5.8 versus 3.6 types. This is consistent with the idea that larger companies have more resource flexibility for investing in new technologies. Their production facilities and organizational systems may also may use more varied processes that can benefit from a wider range of tools.

The technology subjects most often reported using for SM is mobile phones (69%), which makes sense given that the ubiquity of mobile phones lowers the adoption and training costs when adapting them to SM applications. Also commonly used are cloud computing, handheld scanners, cybersecurity, and tablets, all used by at least 45% of companies. Like mobile phones, these technologies are also already well known, widely available, and used in a range of commercial businesses, making them easier to adapt for SM purposes, especially for smaller enterprises. Only a handful of subjects reported that their companies implemented any technologies and later discontinued them. However, many technologies have previously been considered and rejected (thus far) by at least one in ten of these companies, specifically: autonomous robots, handheld scanners, wearable scanners, AR for training, radio frequency identification and real-time locating systems (RFID/RTLS), and 3D printing. These are small numbers so far, but they hint at which tools SMMs might start to branch into, if they gain more traction on SM adoption. By contrast, the vast majority of companies had not even considered adopting smart glasses, VR or AR headsets, wearable scanners or computers, or AI. This detailed breakdown helps to orient SMMs and those helping them toward which solutions are most likely relevant to smaller enterprises, which are not necessarily those gaining the most headlines or being featured by the largest national companies.

SMMs in two industry groups—food and beverages, and metals—use more types of SM on average, while those in the plastics and chemicals group use fewer; these differences only show trend-level statistical significance, but may be more robust in a larger sample and bear further investigation.

When these SMMs do adopt SM technologies, the good news is that they work well in most cases. Subjects report an average satisfaction level across technologies of 4.0 (on a scale of 1 to 5), corresponding to "somewhat satisfied." When asked how most workers reacted to implementing the technology, subjects reported an average reaction of 4.1, corresponding to "somewhat positive" on the five-point scale. Subjects' average satisfaction with individual SM technologies ranged from 3.5 (handheld scanners) to 4.3 (autonomous robots, big data analytics, and 3D printing). However, an average of "somewhat satisfied" or "somewhat positive" can mask a large number of cases with neutral or even negative evaluations. Indeed, more than one in three subjects were less than satisfied with simulation, headsets, and handheld scanners, while more than one in three reported that workers were less than positive about system integration and cyber-security. The precise numeric comparisons should be treated cautiously, given the modest number of subjects reporting on each technology and the unknown other variables involved in implementing them. However, the overall take-away is clear: the challenge is not only motivating and helping SMMs to adopt these SM technologies, but being aware of possible problems once they are implemented and addressing them.

The measures of readiness, implementation, and staffing needs are generally correlated to each other as expected, although not all of the relationships are strong enough to meet statistical significance. Subjects reporting high levels of management and employee support for SM (the readiness index) are more likely to have implemented first concepts or more, and tend to be currently using more SM technologies. Subjects who report higher needs for training and replacing workers in order to adopt SM also tend to score lower on the readiness index, and report more negative responses from workers to SM technologies already adopted. These results speak to the interaction between these three concepts and particularly the importance of training the broader workforce to effectively adopt SM, and of helping smaller companies train and recruit employees to support this process.

In summary, this study shows both how SMMs in Nevada can potentially benefit from smart technologies and the extent of the serious challenges they face when adopting this digital transition. Overall, these results support the idea that SMMs, even more so than larger companies with more flexible resources, should focus on integrating specific technologies tailored to their specific needs rather than attempting to embrace the full spectrum of smart manufacturing at once. This study further adds to prior research by asking about companies' experiences with specific tools. These results inform the development of strategies, outreach, and technological solutions that are affordable and easily adaptable for SMMs by providing quantitative evidence of what SMMs need that many in the field have seen anecdotally. Namely, that lending support to SMMs at these early stages can help pull them out of a cycle of stagnation due to limited resources, limited flexibility, and questionable rewards; financing assistance and better information on how to achieve solid returns on their investment and measure their results may serve as useful tools to advance adoption. More research is needed to gain a better understanding of where SMMS are in their transition to smart manufacturing and what problems they have that would be most responsive to new technology.

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