



IADC/SPE 128953

Advanced Rig Technology: Future Technology Subcommittee Report of Activities and Industry Survey

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This paper was prepared for presentation at the 2010 IADC/SPE Drilling Conference and Exhibition held in New Orleans, Louisiana, USA, 2–4 February 2010.

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Abstract

This paper is intended to report to the industry from the IADC Advanced Rig Technology Committee's Future Technology Subcommittee a survey of the industry regarding industry needs for technological development and how they are valued. The paper will include survey results, as well as discuss ongoing committee work.

The group has produced three sets of deliverables to date. First, they have studied a wide range of technologies that have been introduced to the industry, some well-accepted and rapidly adopted, while others have never grown beyond niche technologies, at best. The paper will highlight learnings and assumptions when the group reviewed common factors that may or may not have contributed to their success.

Second, the team developed a future technology needs survey which was distributed to a wide range of individuals representing all segments of the business, including service firms and suppliers, drilling contractors, and operators, with a specific emphasis on the operating community. The results of that survey will be reported and the findings analyzed and discussed to help develop a landscape of perceived future technology needs.

The third deliverable comes from working with the SPE Drilling Systems Automation Technical Section (DSATS) to create a matrix of drilling operations versus drilling issues, such that the direction of automation and optimization can be more clearly defined.

This paper provides data and analysis along with conclusions which highlight methods and working groups in the industry. It shares some of the valuable results with recommendations for the future investments for the industry to consider in the future development of technology. It will highlight typical restricting practices as well as best in class technology introduction paths.

Introduction

Commissioned by the IADC ART Committee, the objectives of the Future Technology Subcommittee are to educate the industry on the factors that create a successful introduction of new technology, to provide a method for drillers to understand operators' challenges, and for vendors to understand the future needs of drillers and operators. To this end the subcommittee is reporting on three projects completed from 2008-2009. The projects are:

- **Past Technology:** An identification of success factors and associated technical enablers of historical applications.
- **Present Technology:** An examination of the level and competence of automation equipment in our industry today. In association with SPE DSATS, this study highlights successful applications of automation by operation.
- **Future Technology:** Survey-based insight into perceived future technological development needs. Operators, contractors, and vendors providing input to give the reader perspective of perceived operational gaps, where there may be sufficient business needs to drive the next game-changing technological application.

Past Technology

The subcommittee formed in 2008 and began with an effort to identify what can be learned from our successes and failures in the introduction of products and systems. The result (**Fig. 1**) was a detailed matrix cross referencing specific historical applications against their contributing success factors as well as their technical enablers. Contributing factors reviewed

include the number of years to reach commercial success, availability of a financial sponsor, safety or regulatory considerations, and operability and reliability. The technology enablers reviewed identify specific technologies that were required to actually make the application work. Those enablers include availability of faster microprocessors, improved machining techniques, and the advent of the internet.

Analysis of the results showed that successful applications shared similar contributing success factors. First and foremost, the application improved the economics of well delivery. Access to new reserves, reduction of risk, additional efficiency, operability, and safety were all additional contributors. When these elements aligned, they tended to produce game-changing applications such as the top drive, variable frequency drives or rotary steerable. Interestingly, the time to success for most of these game-changing applications was a short three to four years. Apparently, a compelling economic argument can overcome many operational and cultural obstacles.

Review of the technology enablers showed significantly fewer common threads although sensor technology and human machine interface (HMI) maturity did appear quite often. Contrary to perception, there appeared few common connections to advancements in other industries (i.e., mining) or advancements in specific technologies (computer processor speed), with a notable exception that locomotive technology enabled top drives.

Defining and agreeing on what constitutes a successful application of technology was the subcommittee's first hurdle. A successful application was agreed to be something that was commercially successful within a three to eight-year time frame while addressing a real engineering need across a broad market segment. The subcommittee recognized that the drilling industry, as a market segment, is heterogeneous consisting of wide variances in geography, applications, investment requirements, etc. An application was not considered a success unless it had a broad impact across multiple segments. An unsuccessful technology, besides commercial lackluster, is something that has not yet had broad use despite a reasonable period on the market (>15 years). Three case studies highlight the past, present, and future of a specific application. The paper examines the top drive, Managed Pressure Drilling (MPD), and SafetyBrick©.

Learning from the Past – Three Case Studies

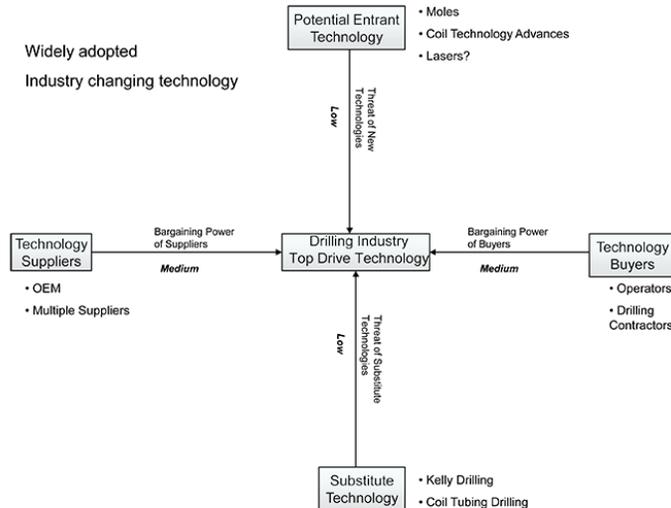
Top Drive – Success. (Fig. 2) The idea of top drives began with the development of the power swivel in the late 1940s. Companies focused on hydraulic power swivels and played with electrically powered swivels also. Adding a pipe handler to the bottom of the power swivel transformed it into the top drive. The first top drive was developed in 1981 for Sedco to address needs in the industry for a machine that could handle pipe, make and break connections remotely above the drill floor, drill with doubles or triples, back-ream, and maintain circulation longer. Prior advances in locomotive technology from GE and GM laid the foundation for the DC drilling motor technology.

There are several intertwined factors that contributed to the success of the top drive. First, the original equipment manufacturer (OEM) partnered with an innovative and committed customer that was willing to take a risk for potentially large increases in efficiency. Secondly, the OEM was fully committed to R&D of the top drive system (TDS) and aggressively pursued sales and marketing. There were typical problems associated with product development but after a few iterations and the development of the TDS-3 commercialization was around the corner. The industry learned about the potential for this new tool when the top drive gained public attention. The limelight followed a series of industry design awards for the top drive and an article by an SPE publication from Mobil Exploration-Norway which was based on their success with deviated wells on the Statfjord platforms. It was not until 1987 that the OEM had turned to profitability. The adoption of top drives became an economic necessity for operators and contractors if they were going to be competitive in future markets. The top drive is viewed as a game-changer because of its revolutionary effect on present and future technologies and because it was an enabler for advanced directional drilling applications.

Since the mid-80s drilling engineers have been pushing top drives and drilling systems to the limit and have been demanding more robust solutions. Top drives are now on roughly 95% of all offshore drilling rigs and 50% of onshore drilling rigs. (Sources: BHI Rig Count, MI Rig Count, Schlumberger Rig Count, TESCO Research and Estimates) Even though top drives have been one of the highest sources of rig-down time they have offered an enormous source of economic value with their capabilities.

Our future relies on incremental improvements in drilling with the occasional leap forward in technology such as the top drive. Top drives will continue to evolve to meet the increasing demands of offshore drilling, particularly to develop tools that are more capable, more reliable, and safer. Extreme reach wells are requiring more drilling torque, and load capacity. In the future, control systems will provide closed loop communications between downhole drilling tools and the topside drilling package to more precisely control conditions such as weight on the bit, circulation, and downhole drillstring vibrations. The industry is evolving from strictly tool based technologies to closed loop system technologies that will operate in synchrony.

Fig. 2



Managed Pressure Drilling (MPD) – Possible Success. (Fig. 3) In contrast to the top drive, which is an unqualified success because of its ability to deliver economic value across a large market, it is the Future Technology Subcommittee’s opinion that MPD is a potential but not yet definite success. MPD is an adaptive process used to precisely control the annular pressure profile throughout the wellbore (1). It is particularly helpful, and sometimes essential, in drilling wellbores through areas of tight pore pressure / fracture gradient margin. MPD can include control of backpressure, fluid density, fluid rheology, annular fluid level, circulating friction, and hole geometry, or combinations thereof (1). Examples of MPD technologies are dual gradient drilling, mudcap drilling, and constant bottomhole pressure (CBHP) drilling.

While some forms of MPD can be traced back many years, it is within the past decade that most critical applications requiring its use have arisen. These usually have been in mature formations with depleted reservoirs. Thanks to early sponsorship by operators such as Shell and ConocoPhillips, MPD technology has developed to address these “must have it to drill” applications, with compelling results. Aging platforms have been rejuvenated and “undrillable” wells have been drilled throughout the world. MPD engineering consultancy, service companies, and equipment suppliers have all developed to support this growing need.

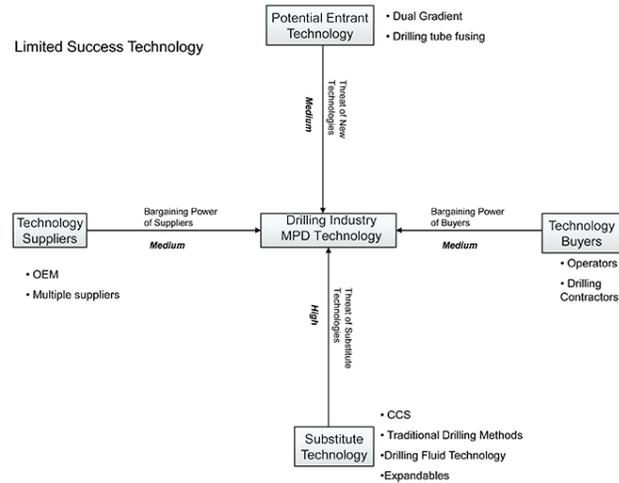
However, despite its unquestioned ability to deliver economic value, MPD has yet to fulfill its potential across a broad market. In particular, CBHP MPD has this potential since its equipment (a rotating control head, a surface choke, drillpipe float, a flowmeter, and pressure sensors) can be applied to most drilling rigs. In addition to dealing with tight pressure regimes, CBHP can potentially be routinely used to safely drill close to pore pressure, thus avoiding stuck pipe and lost circulation, increasing ROP, and sometimes saving casing strings. CBHP can also be used to manage wellbore stability and enhance kick responsiveness. To reach this larger market, issues which must be addressed are:

- Continued efforts to reduce the number of personnel and cost of equipment and services to deploy MPD
- Continued responsiveness to regulatory requirements and safety considerations worldwide
- Continued education and evangelization of MPD applications and operational practices to drillers and operators

The need to address these issues is keenly felt in the industry, and all segments are actively working to resolve them. Special mention must be made of the IADC Underbalanced Operations and Managed Pressure Drilling Committee, comprising operators, drilling contractors, service companies, equipment suppliers, and regulators working to advance MPD and UBO technology in the most expedient, and safest, means possible. The IADC/UBO Committee has worked steadily and effectively to define MPD and clarify the issues surrounding it. Most recently, this committee was instrumental in assisting in the US Minerals Management Service (MMS), which issued its Notice to Lessees and Operators (NTL) for Managed Pressure Drilling. Other IADC UBO/MPD Committee contributions include a classification system for UBO and MPD, a Standards Gap Analysis, glossary of terms, and API Manufactured Equipment Standards for Rotating Control Devices and Non-return Valves.

As a result of its proven economic value and industry efforts to advance the technology beyond “must have” applications, it appears that the day of MPD’s outright success as a broadly applied new technology will come. But that day is not today.

Fig. 3

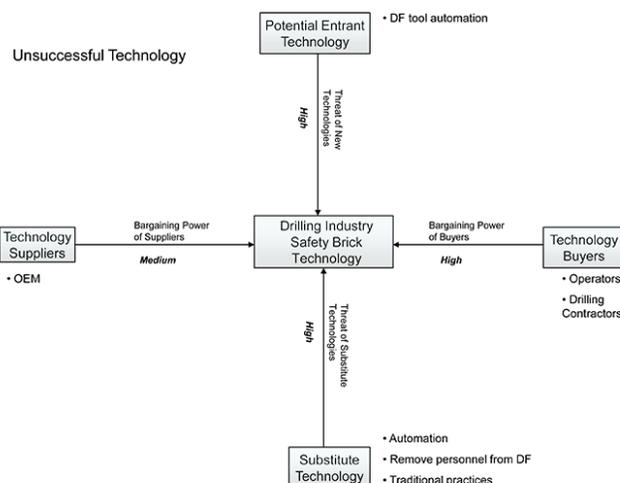


SafetyBrick – Unsuccessful to Date. (Fig. 4) The SafetyBrick System was designed to prevent accidents and injuries around the drilling operation. SafetyBrick reduced risks to personnel by tracking their movement in dangerous areas occupied by moving equipment. This resulted in a safer and more efficient work environment. The basic system consisted of protective footwear that houses the inductive shoe charger and transponder reader electronics which includes RFID antennas, a radio antenna, a battery charge coil, and PCBs. The smart safety floor mat was embedded with transponders and approximately 27 RFID passive transponders are distributed throughout the mat between each transponder. People on the drill floor wore an encapsulated transponder reader. The reader transmitted in realtime any movement by personnel (identified by the reader antenna) provided the reader was within 30 cm of any transponder. The location of personnel wearing reader footwear was tracked in realtime when they step on the mat. If someone wearing the SafetyBrick is subjected to danger while they are on the mat, the impending machine is automatically halted.

The SafetyBrick project kicked off in the spring of 2004 and was presented at Offshore Northern Seas Exhibition and Conference the same year. The concept was well received and consequently funded by an operator in Norway in addition to the product's original equipment manufacturer (OEM). The SafetyBrick System developed for drill floors goes unnoticed by the person who wears it and could be seen as a virtual air bag containing a built in emergency stop feature, this to make it a complementary safety barrier to any local machinery emergency stop buttons.

In spite of its technical success and its initial sponsorship by a major operator, adoption of SafetyBrick has lagged. Speaking generally, it appears that most operators perceived that investments in people (e.g., training) and process would yield greater and broader-based results than investment in specific technology-only solutions like SafetyBrick. It is possible that once benefits from people and process improvement level out, operators will turn to technology solutions to continue improvement, but for the moment it appears SafetyBrick was possibly the right technology, but definitely the wrong time.

Fig. 4



Conclusions From The Past

Economics played a major role in history success stories. The three technology examples mentioned illustrate the differences between the commercialization of a game-changing technology, limited success technology, and lastly an unsuccessful technology. Each technology was developed to address a specific set of needs ranging from drilling efficiencies to safety. It is important to understand how certain technologies such as top drives have revolutionized the industry while promising technologies such as MPD have not yet been adopted fully. The commercialization of a technology is dependent on several factors that must all be present for a game-changing technology such as the top drive.

The following factors for widespread commercialization are not comprehensive but offer insight into the success and/or failure of a technology:

- Fulfills a clear and compelling need
- Enabler/catalyst of future technologies
- Disruptive technology
- Addresses entire value chain
- Committed R&D team to see product through commercialization

Present Technology – In Partnership with SPE Drilling Systems Automation Technical Section (DSATS)

From working with the SPE DSATS, the IADC ART Future Technology Subcommittee set out to understand where and how well automation plays a role in operations today. The result (**Fig. 5**) is a ranked matrix of automation applications by operational stage.

SPE's DSATS has been looking into the current state of the drilling industry when it comes to automation of the entire drilling process. Typically there has been a line drawn between drilling equipment at the surface and downhole equipment and systems. The automation systems for those two sub-groups have typically operated independently from one another. DSATS is working to define and push the industry in a direction where we can close the loop on drilling controls by having the needs of the downhole equipment control the surface equipment. In order to progress in this area, IADC's ART Future Technology Subcommittee has put together a matrix which defines typical drilling operations / activities along the columns and identifies common issues experienced during well construction. The intent of the matrix is to pinpoint where we are today with typical operations and their issues, so we may recognize where one issue impacts multiple types of activities. Once identified, the industry can get a clearer understanding of what is the best technical challenge to attack first. The matrix (**Fig. 5**) created by the Future Technology Subcommittee is the skeleton with the intent for the DSATS experts to fill in the blanks to help the industry determine its future direction. The matrix is not unchangeable, but instead should be a living document to progress as the industry progresses in drilling system automation technology.

The activities identified are:

- Vertical Rotary Drilling
- Directional Slide Drilling
- Directional Rotary Steerable Drilling
- Reaming / Back Reaming
- Tripping
- Circulating
- Running Casing
- Cementing
- Surveying
- MPD Operations

The potential issues identified are:

- Stick / Slip
- Balling/Stuck Pipe
- Extended Reach Drilling – Pipe Friction
- Exceeding Pore / Frac Pressure Limits
- High Temperature
- Excessive Vibration
- Lost Circulation
- Pump Noise (survey impact)
- Pack Off
- Porpoising / not smooth borehole

- High Dog Legs
- Micro Tortuosity
- High Downhole Pressure
- High Downhole Temperature

Future Technology

In an attempt to provide some forward-looking insight towards the next game-changing application, the subcommittee polled the community. A Future Technology survey was designed for operators, vendors and contractors to identify the biggest economic and operational pain points in the industry. Across a broad spectrum of operational areas (**Figs. 6-24**) participants were asked to rank technologies on performance, relative cost and Future Technology Development (FTD) on a scale of 1 to 10. For performance a rank of '1' indicated low positive industry impact, while '10' indicated significant impact. For relative cost a rank of 'low' indicated the application cost less than others, while 'high' gave the indication of significant perceived financial burden. The FTD portion allowed those surveyed to give a more subjective indication of where they felt development dollars should be spent to improve the applied technology.

Future Tech Survey

Survey Purpose. With all the possible areas of focus for technological advancement within the industry, it is necessary to gauge which previous innovations have been viewed as successful, as well as which ones will need further attention. Though IADC has at its fingertips access to the opinions of many of the oil and gas industry's astute, it is also apparent that the collected opinion of a crowd is statistically more accurate than that of any individual. With that, the objective of the IADC Future Technology survey is simple: to accurately gauge the industry's positions in regards to which technological advances have performed well and which are in need of future development.

Survey Structure. With the intention of gauging two key characteristics over a wide variety of topics, every question was given two possible answers: *Performs Well* and *Needs Development*. The areas in which these questions were focused were as follows:

Downhole Survey

- Drill Bits
- Directional Drilling
- PWD/MWD/LWD Downhole Tools
- MPD
- MPD Equipment
- MPD Technology
- Downhole Equipment

Rig Floor Survey

- String Torque
- Pipe Handling
- Hoisting
- Mud Flow/MPD
- Motion Compensation

Rig Floor Equipment

- Health, Safety, and Environment
- Manpower
- Safety Issues
- Health Issues
- Environmental Issues

The questions were structured to give results on several characteristics within each area, as such (**Fig. 25**):

Fig. 25

Downhole Equipment	Performs Well (1)	Development Needed (3)
Accuracy	<input type="checkbox"/>	<input type="checkbox"/>
Automation	<input type="checkbox"/>	<input type="checkbox"/>
Cost	<input type="checkbox"/>	<input type="checkbox"/>
Maintainability	<input type="checkbox"/>	<input type="checkbox"/>
Reliability	<input type="checkbox"/>	<input type="checkbox"/>
Other (please specify)		

Though the two characteristics of 'performs well' and 'needs development' at first glance would seem to be exclusively dichotomous (requiring an answer of either one or the other), it was decided upon further consideration to not enforce this as a stipulation. Respondents were given the option to choose 'performs well', 'needs development', or both options. This allowed us not only to identify areas that are exclusive performing well or needing development, but also to identify areas where the industry has generally been impressed with the success of a technology *and* still sees room for improvement. Forcing respondents to choose one or the other wouldn't allow us to identify such perspectives. For instance, 'Mud Flow/MPD Solids Control' rated relatively high in the 'performs well' category indicating there has been considerable improvement in the solids control of mud flow and MPD, yet it also scored relatively high in the 'needs development' category, indicating a desire for further improvement. In other words, it sure isn't what it used to be, but it still isn't what it could be.

This was only the case with a select few topics. For the rest, there is a clearly inverse relationship between 'performs well' and 'needs development'. Where one ranks high, the other is low, and vice versa. The 'Drill Bits' results graph is a key illustration of this.

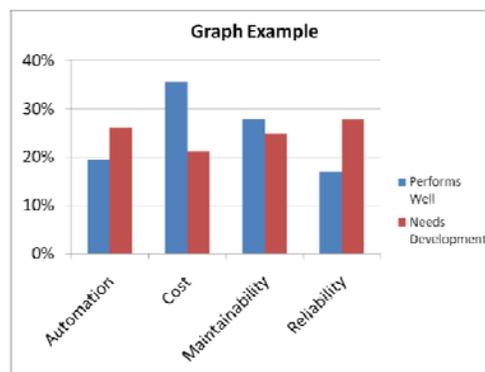
In retrospect, there are a few regrets concerning the design of the survey. First, by not forcing the respondent to choose either 'Performs Well' or 'Needs Development', the extent to which we could compare and contrast the two options was somewhat disabled (even though we were advantageously able to identify topics where these options were *not* seen as opposites).

The second mistake was encouraging respondents to choose *one* 'performs well' answer per topic and *three* 'needs development' answer per topic. This was decided with intentions to focus more on the importance of what technologies need development rather than what already performs well. In hindsight, this was not necessary and forced us to base the percentages off of the number of people who chose each option per question as opposed to basing it off of the total number of people who answered each question. While it was possible to rectify this, it certainly caused more work in interpreting the raw data and presenting comparably normalized results.

Lastly, by having specialists from each field of interest design their own set of questions, it was difficult to maintain a congruent set of answer options across all questions. While this is not detractive to the results, it does inhibit the ability to compare results across questions and limits the analyses to each question alone. *Ceteris paribus*, the fore mentioned shortsightedness was not enough to keep the survey from producing some fascinating, reliable, and useful results.

Survey Implications. Some of the survey results implications are simple and easily recognized. Anytime "Performs Well" receives significantly higher marks than "Needs Development", this generally indicates an overall satisfaction with the performance in that area. As an example, hoisting capacity is a clear leader in satisfactory performance (**Fig. 26**).

Fig. 26



Likewise, if "Needs Development" significantly outweighs "Performs Well", this would indicate a general desire for improvements to be made in that area, such as in the case with drillpipe fatigue monitoring.

In addition to the simple conclusions, some speculations could be made from combinations of results. For instance, in almost all occasions where maintainability and reliability were polled on the same topic, maintainability received high votes in “performs well” and reliability received high votes in “needs development”. One possible supposition that could be made about this combination is that while equipment is often easy to maintain, it breaks down or malfunctions too often. Other similar or more extensive conclusions can be made from further study of the graphs supplied in the appendix. (Figs. 6-24)

Conclusions

As the IADC ART Future Technology Subcommittee continues to strive towards its goals it(we) hope(s) this report on past, present and future technology indicators is insightful to the industry. We also look to encourage future sharing and cooperation between operators, contractors and suppliers.

References

(1) definitions of MPD from "UBO & MPD Glossary", available from IADC through the link http://www.iadc.org/committees/ubo_mpd/completed_documents.html

Figs. 6-24

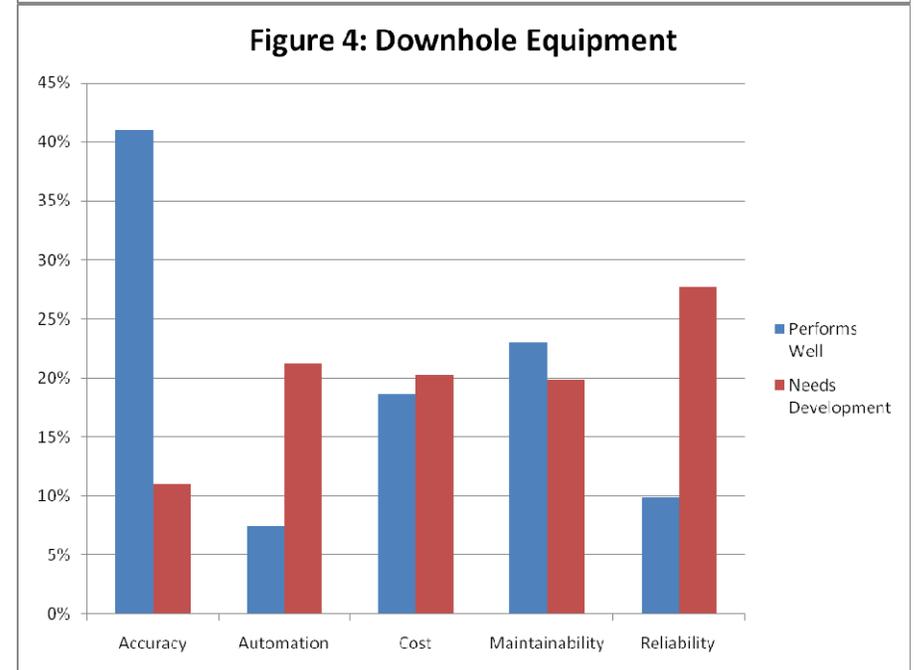
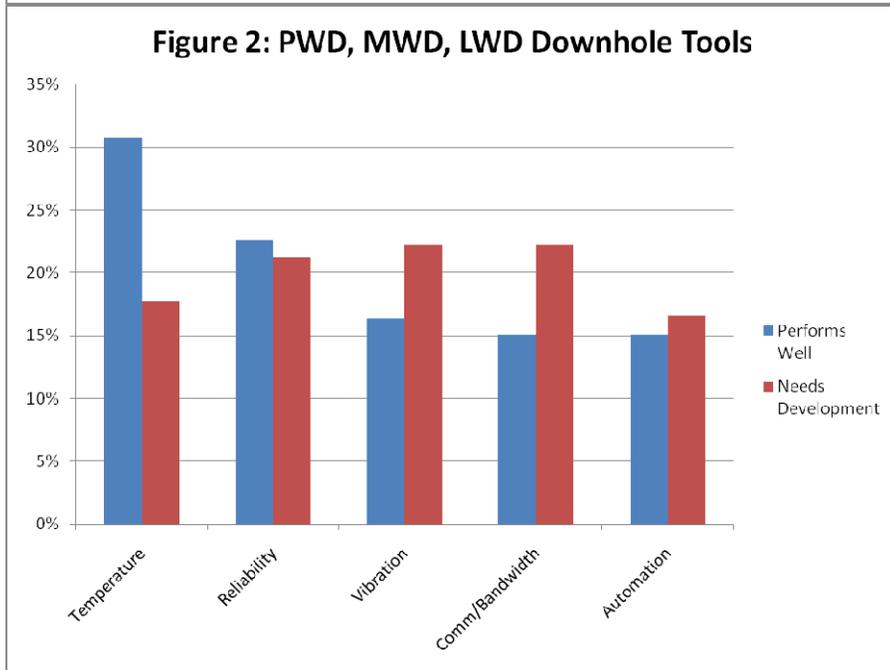
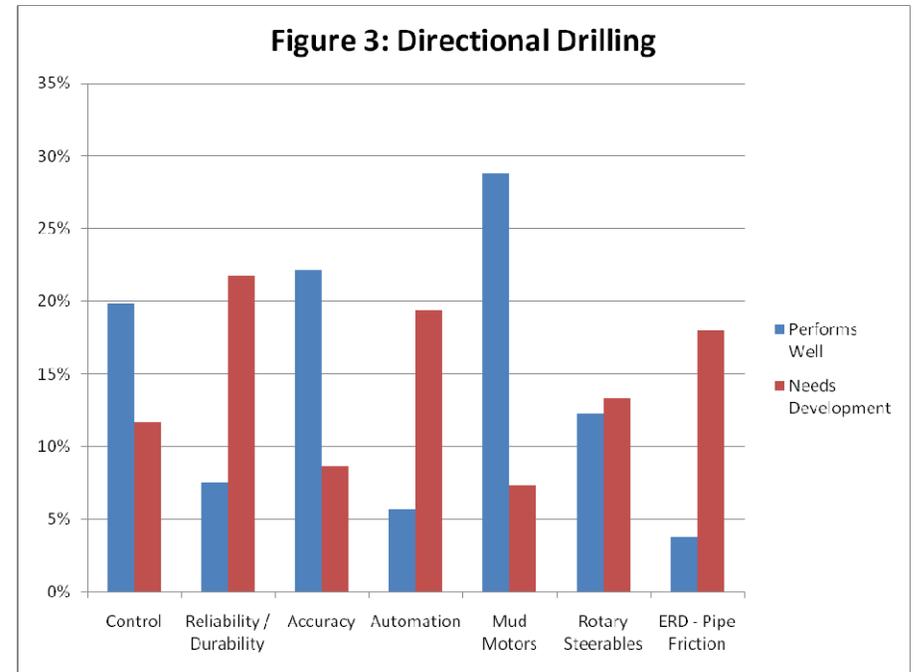
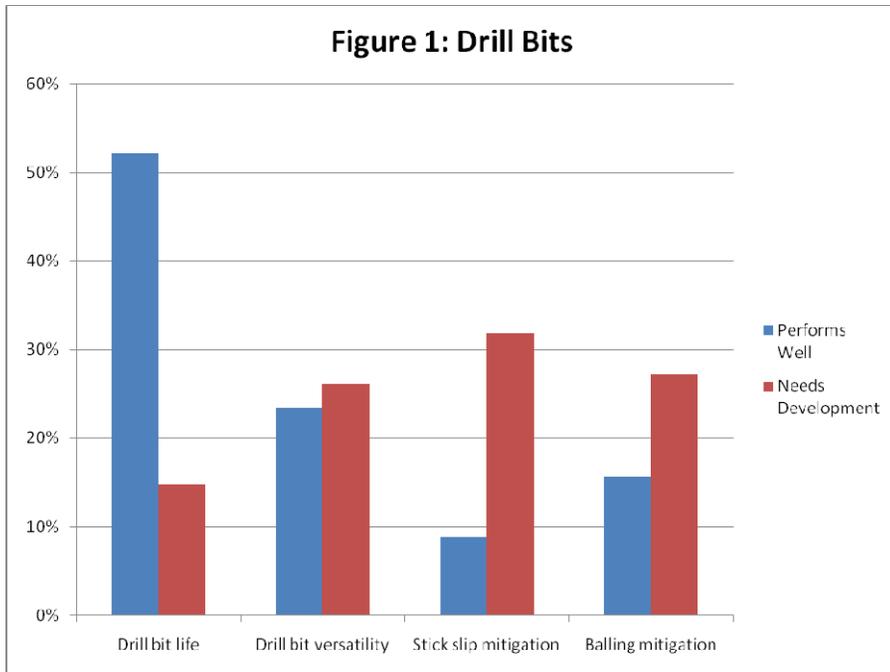


Figure 5: MPD

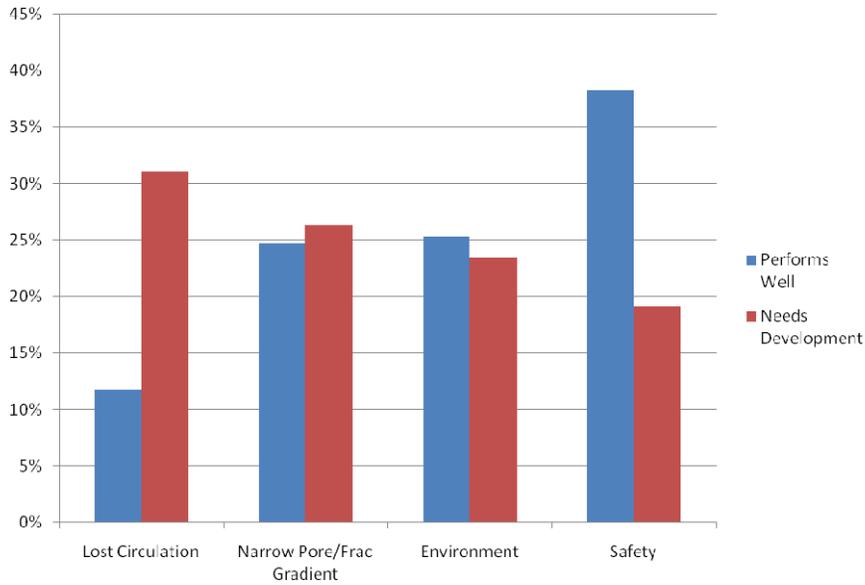


Figure 7: MPD Equipment

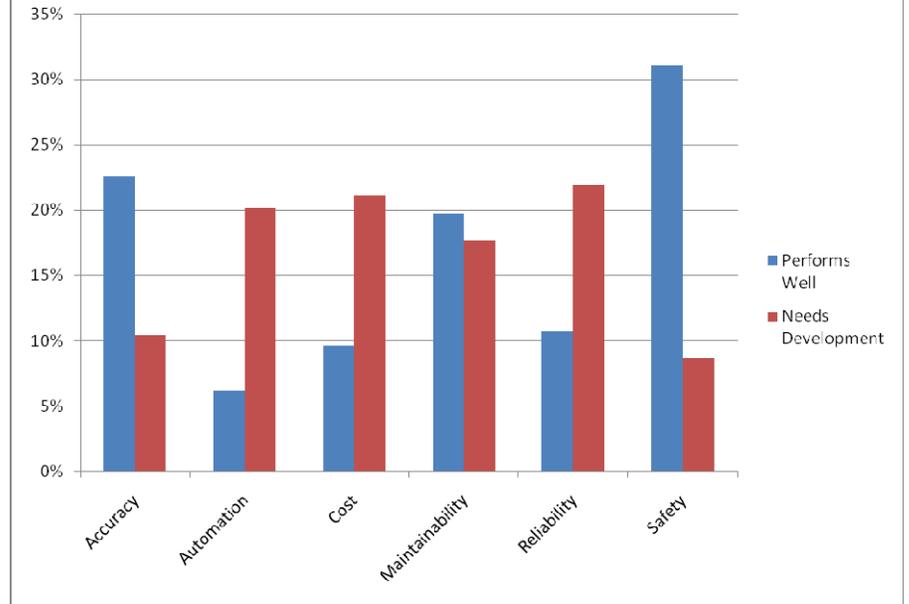


Figure 6: MPD Technology

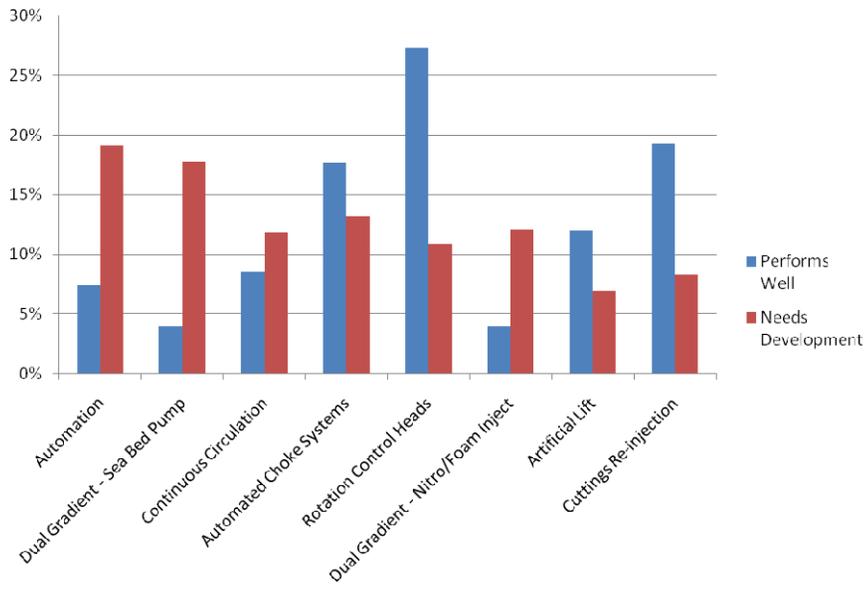


Figure 8: String Torque

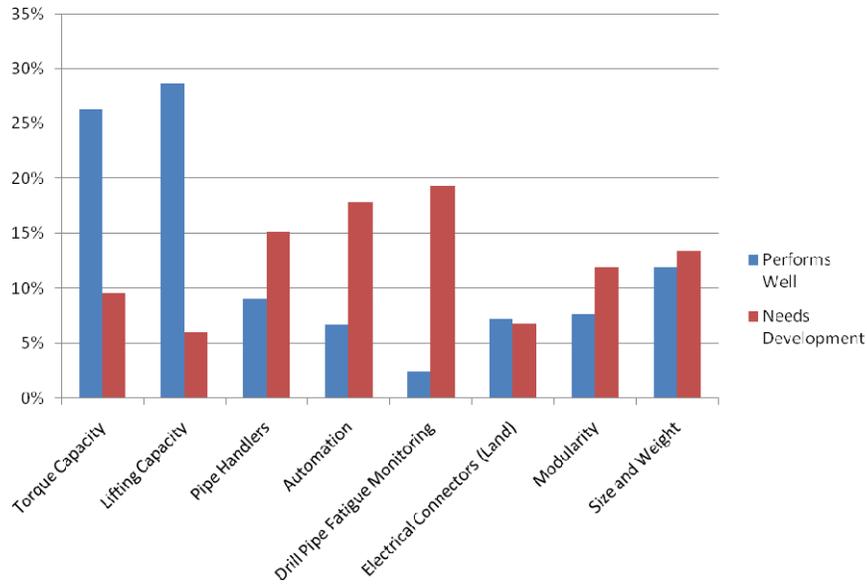


Figure 10: Hoisting

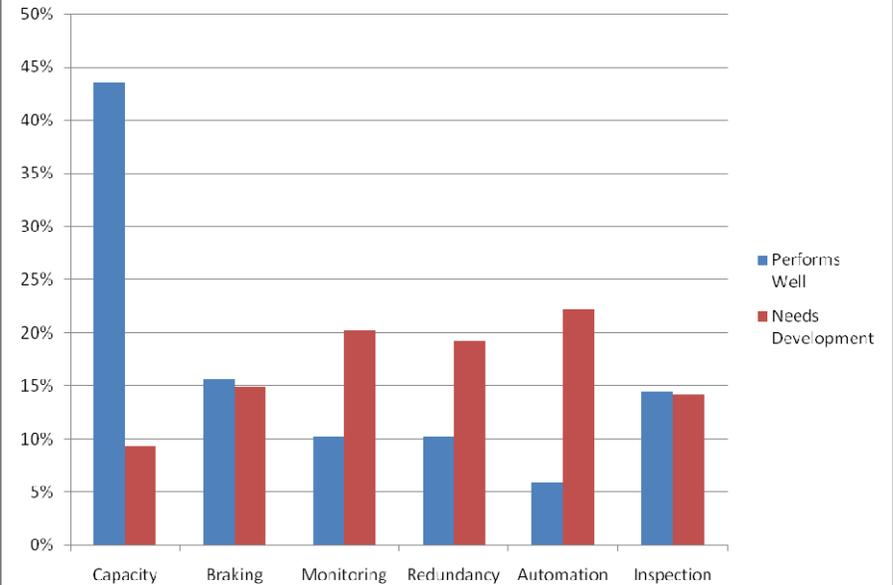


Figure 9: Pipe Handling

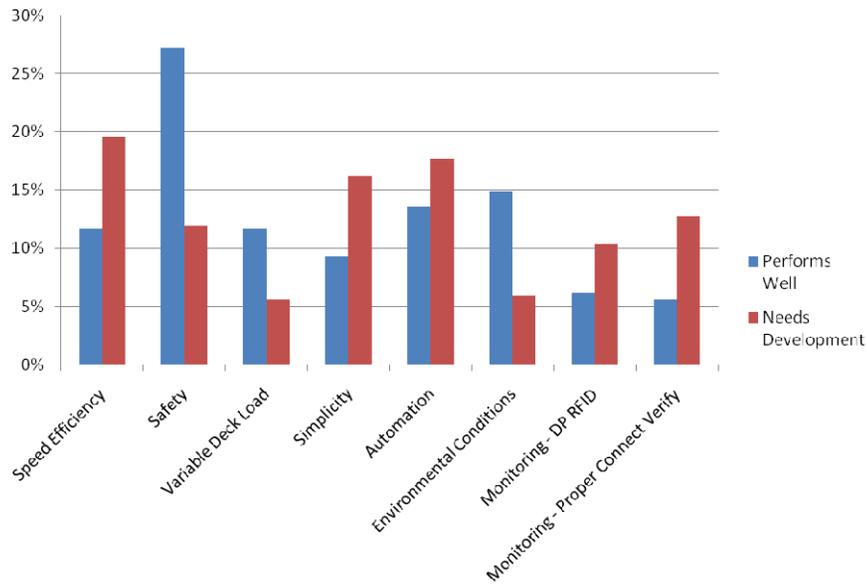


Figure 11: Mud Flow/MPD

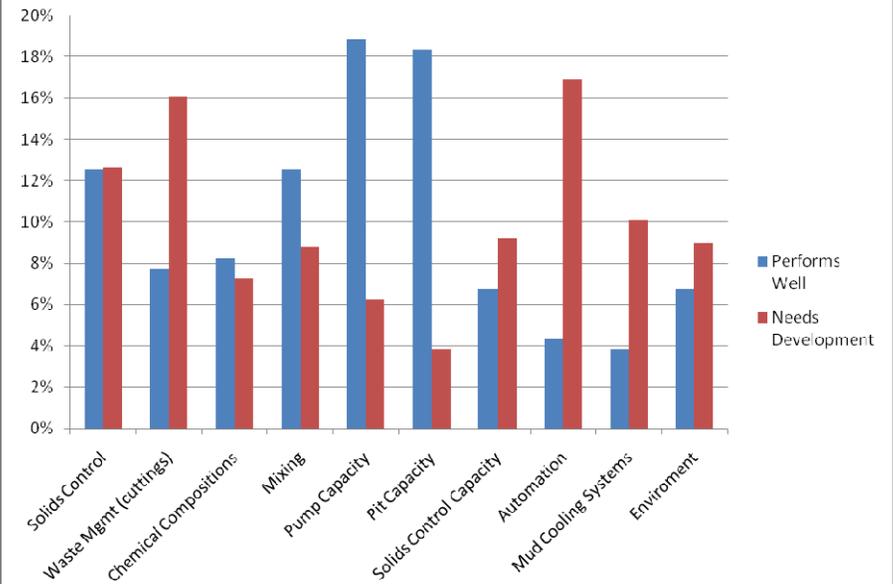


Figure 12: Motion Compensation

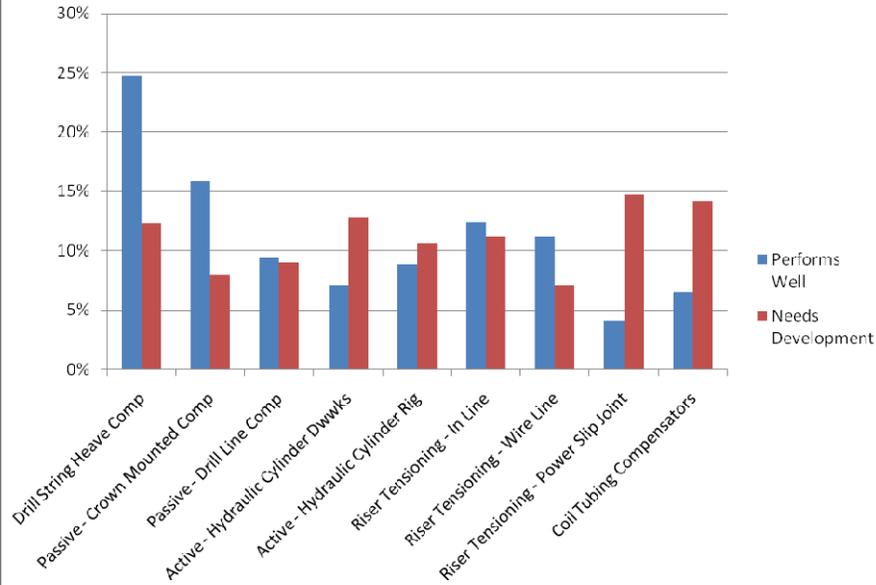


Figure 14: Pressure Control Equipment

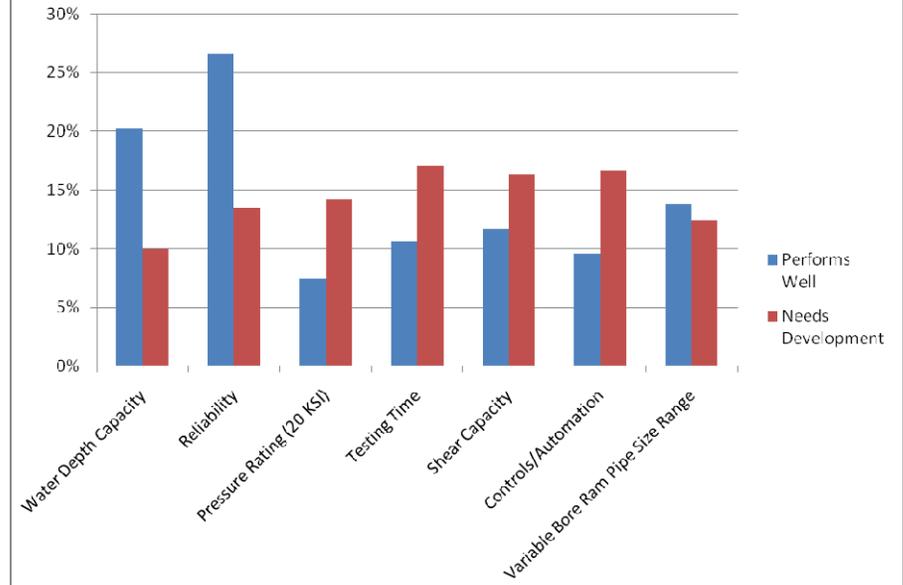


Figure 13: Rig Floor Equipment

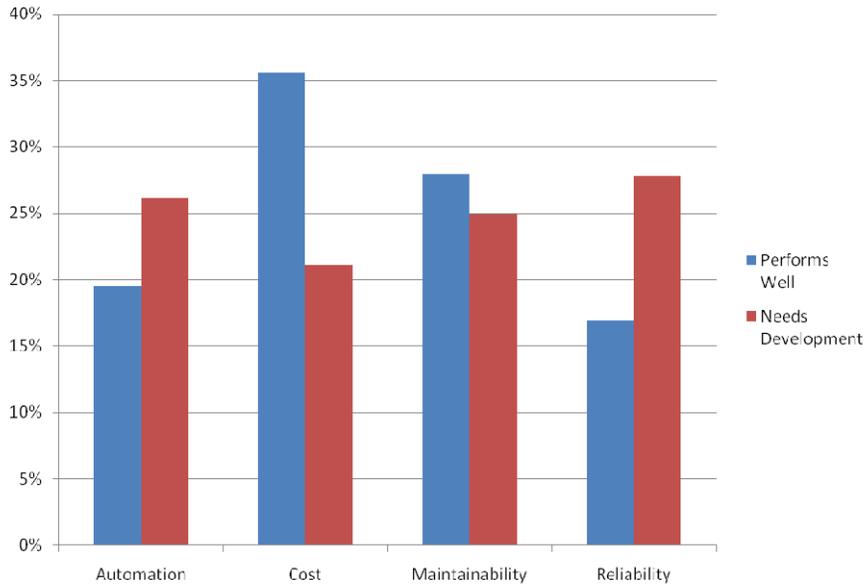


Figure 15: Pressure Control

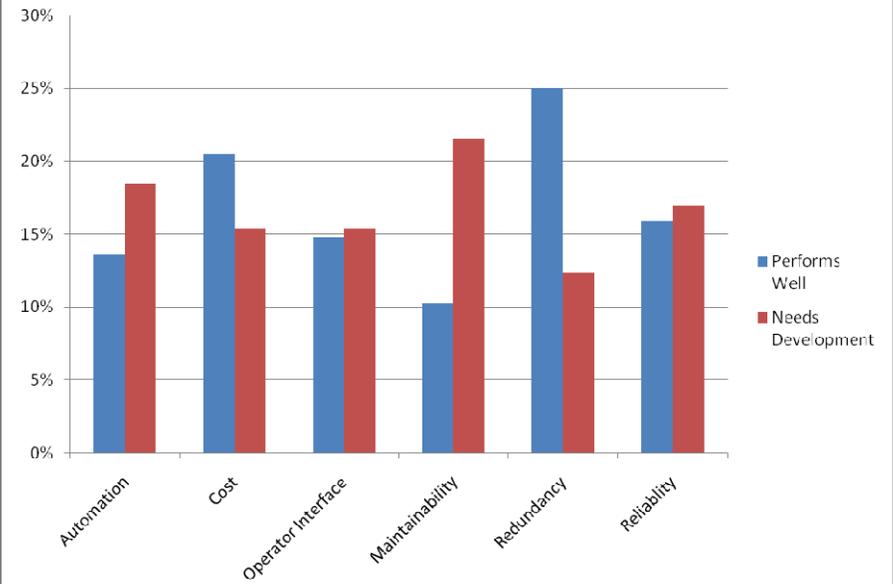


Figure 16: Manpower

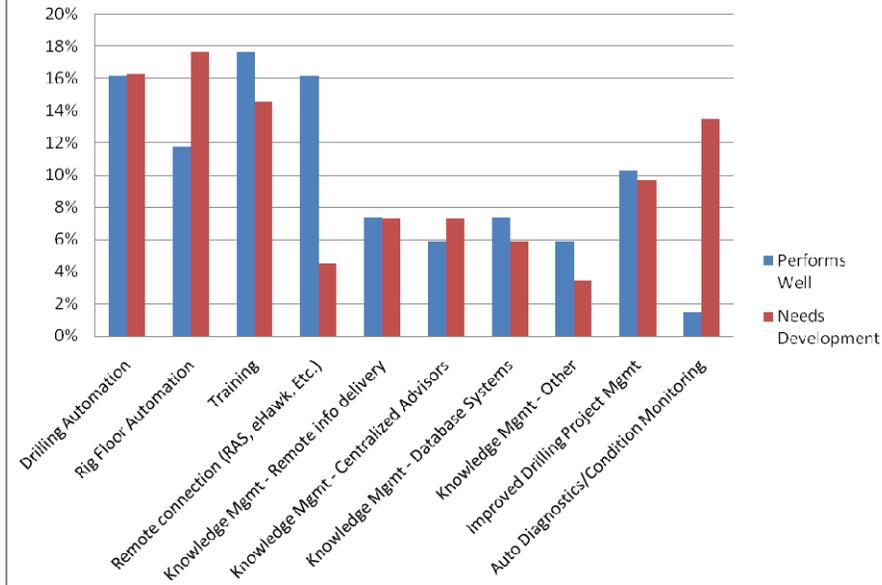


Figure 18: Safety Issues

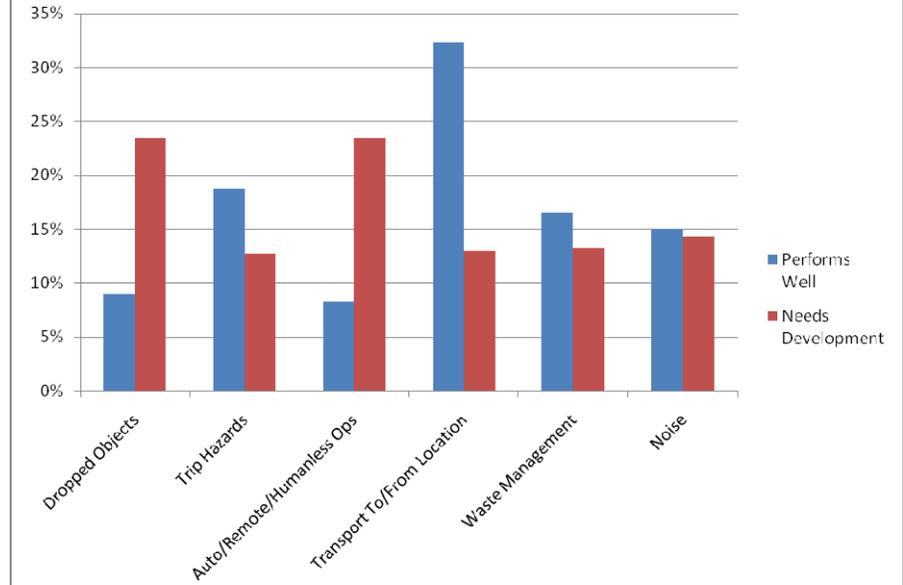


Figure 17: Health Issues

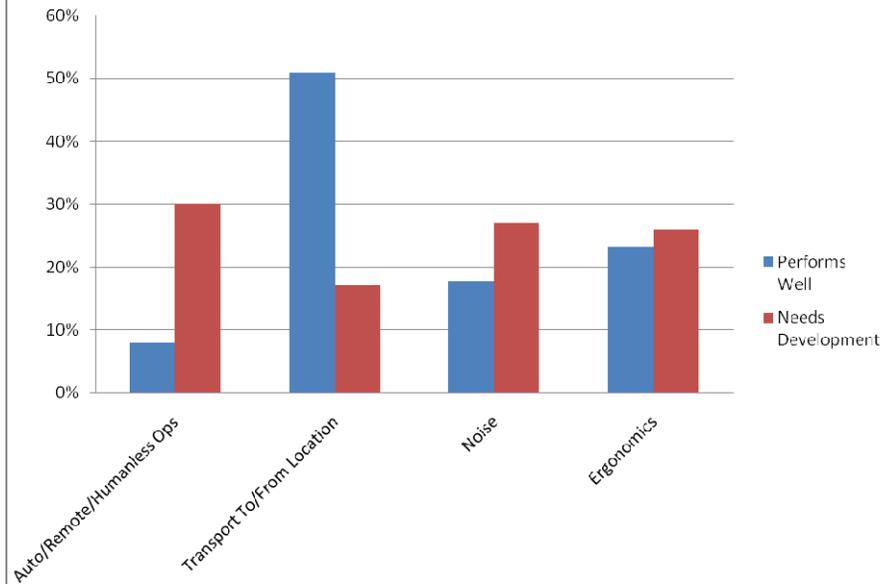


Figure 19: Environmental Issues

