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Accounting Problems Influencing the Diffusion of Nanotechnology Implementation in Developing Countries: The Case of Jordanian Companies

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This paper purposes to explore Jordanian companies' accounting reasons for avoiding a transition toward more advanced industrial techniques; namely, to nanotechnology. This advanced technology could have many benefits to the firms, as it can decrease the cost of products, enhance products' quality and produce products quickly. Both quantitative and qualitative data were gathered for this study. For the quantitative data, a questionnaire survey was developed in order to collect information about the respondents and to determine the accounting barriers and problems present in the implementation of nanotechnology. For the qualitative data, semi-structured interviews were conducted to determine the accounting barriers and problems impacting the implementation of nanotechnology. This was to confirm the quantitative results and to add additional information. The questionnaire data analysis was descriptive in nature, while the qualitative analysis was included within both the analysis and cross-analysis. Findings from both the questionnaire and the semi-structured interviews reveal that accounting factors such as lack of capital, lack of adequate funding, cost structure distortion and poor insurance all minimise the diffusion of nanotechnology in Jordanian Companies. The findings from the interviews also reveal that the accounting barriers to nanotechnology implementation are associated with low economic growth in Jordan and the Jordanian universities' budget deficit. This study contributes to the further acquisition of knowledge regarding the diffusion of nanotechnology, providing a basis for further research in Jordan and other developing countries. To my

knowledge, this is the first study conducted on this subject. Furthermore, this study's contribution to this field of research will help facilitate the implementation of nanotechnology within Jordanian companies. However, accounting factors play a significant role in determining the success or failure of nanotechnology implementations. As a result, companies must take these factors into account before, during and after nanotechnology implementation, and they must adjust their expectations regarding the results they wish to attain and the speed at which they intend to produce better outcomes.

Key words: *Nanotechnology, Accounting, Management Accounting, Industrial Companies.*

Introduction

Nanotechnology is a new technology in the industry. This technology depends on the assumption that products will display different characteristics if they are produced at the nano level. Nano is a metric prefix meaning one billionth; when combined with a unit of measurement, such as a metre, the nanometre results, amounting to one billionth of a metre. This equals ten times the atomic measurement unit known as an angstrom. Nanotechnology, which is manipulated at the dimension of 1–100 nm, leads to the production of new products and material—specifically graphic and carbon. This advanced technology will enhance energy conversion and storage with optimal characteristics (i.e. small size, large surface area to mass ratio) to be employed in energy efficient, and economically and environmentally sustainable, green innovations (Dai, Chang, Baek, and Lu 2012). Existing literature reveals that labs and factories produced some nano-material over the past 25 years, such as graphene and carbon nanotubes; in addition, they developed high-performance energy conversions such as fuel cells, and, finally, storage devices, such as batteries (Iavicoli, Leso, Ricciardi, Hodson and Hoover 2014).

Many countries around the world, especially developed countries, paid attention to the use of nanotechnology in the industry, establishing labs and nano-factories. These factories produced many types of products, depending on various nano applications; there are more than 1,814 nano products produced around the world (Vance et al. 2015). In addition, there are 622 companies within 32 countries that are producing products that are dependent on nanotechnology.

Many have benefited from the implementation of nanotechnology in the industry, yet its implementation in eastern countries remains low. The websites for the companies that are using nanotechnology do not include any companies located in the Middle East, with the exception of Turkey, which has started using nanotechnology for some activities. Aydogan-

Duda (2012) classifies countries in three categories, regarding their approach to nanotechnology. These categories include "national activity or funding" (such as in the USA),"individual or group research"(such as in Jordan), and "country of interest" (such as in Albania). However, the distribution of nanotechnology activity by country and classification reveals that most developed countries are using nanotechnology in their factories, and most of the developing countries, such as Jordan, are still within the "individual or group research" category. This will create competition problems for these countries in the future. Researchers also mention some accounting problems for the companies that are currently using nanotechnology to produce products or perform services, especially regarding changes in cost structure and increasing fixed cost level which need more accurate allocation to the unit of product (Rababah 2017).

Aydogan-Duda (2012) states there is a need to implement nanotechnology in developing countries because non-implementation will reduce the general demand for these countries' exports. Aydogan-Duda (2012) also notes that the applications of nanotechnology in a developing country are different than when they are applied in a developed country; he adds that a few nanotech projects specifically target the needs of the poor, leading to fears of a "nano divide," similar to the digital divide. In February of 2005, at the UNIDO's International Centre for Science and High Technology's meeting titled, "North-South Dialogue on Nanotechnology," participants stated that most of the nanotechnology applications in developing countries will influence the areas' water, agriculture, nutrition, health, energy and environment by 2015. Meanwhile, in developed countries, most of the applications will influence electronics, computing, pharmaceuticals and other health sectors. As a result, the barriers and obstacles that face the implementation of nanotechnology in developing countries will differ because the application processes are different.

However, there is a lack of research focused on exploring the relevant barriers and problems to the implementation of nanotechnology within the realm of accounting. These barriers and problems represent the issues that forbid implementation or the accounting difficulties that may be encountered during the implementation of nanotechnology—especially during the first stages of implementation—eventually causing companies to abandon implementation. Another set of problems resulting from the use of nanotechnology influences the product cost structure used to calculate the unit of product cost. As a result, in this study I will try to investigate both problems, the first type involving financing and accounting problems before and during nanotechnology implementation, and the second type involving changes in cost structure and product cost.

The Hashemite Kingdom of Jordan, an Arab kingdom within this developing country, began considering the development of nanotechnology and the possibility of employing it in their industries. Resultantly, they established a Nanotechnology Institute at Jordan University of

Science and Technology (JUST) in 2010, contributing to national and international efforts to achieve nanotechnology-based solutions to problems related to water treatment, healthcare and energy.

In this current study, a mixed methodology was used. First, a questionnaire survey was used to reveal the accounting barriers and problems that nanotechnology implementation is encountering in Jordan. Second, face-to-face interviews were carried out with managers and professional employees at the Nanotechnology Institute at JUST to confirm, illustrate and interpret the findings of the questionnaire survey. Furthermore, the interviews were conducted to include additional information regarding the barriers and problems of implementing nanotechnology in the field of accounting, as well as potential effects on the products that are produced through nanotechnology implementation.

I conducted this research at the Nanotechnology Institute at JUST because I believe that it is a suitable environment to provide the most information necessary to complete this research; furthermore, there are currently no manufacturing companies that are implementing nanotechnology in Jordan at this time. Previous studies such as by Guerrero and Urbano (2012), as well as by Rahim, Mohamed and Amrin (2015), state that universities are commonly known as one of the sources of technological innovation, and play an important role in transferring this technology and expertise to the market. With sufficient and supportive technology transfer infrastructure in place, academic entrepreneurs may form start-up companies and make profits based on the innovations generated from their intellectual property.

Furthermore, the existing literature on nanotechnology has focused largely on science and technology, whereas the role of accounting in nanotechnology diffusion has not been widely discussed (Rababah 2017). This suggests that further research is needed to develop our understanding of the role of accounting in the development of nanotechnology, as well as the influence of nanotechnology on accounting issues. Venkataraman, MacMillan and McGrath (1990) state that academic researchers are capable of inventing and developing good innovations, but may not have the necessary business skills and social capital that are essential to the transfer and realisation of technology within the marketplace. As a result, this study will increase awareness levels regarding accounting issues and will open the door for more cooperation between company's managers, technicians and accountants for the purpose of overcoming these problems in the future. To better understand these issues and problems, an analysis was performed, based on the questionnaires and interviews with managers and professional employees at the Nanotechnology Institute at JUST.

This paper contains five sections. The previous, first section introduced the subject of nanotechnology and the presence of accounting-related research issues. The following section

contains a literature review on the subject of nanotechnology. The research design and methodology of this study is presented in the third section. The fourth section covers this study's research results and data analysis. Finally, the conclusion contains ideas and recommendations for future research on this subject.

Literature Review

Nanotechnology in the New Economic Environment

In the past, the field of industrial engineering had technology that was known for their length in micro-electronics but in the present time, developments have been made in the form of nanotechnology. Specifically, nanotechnology refers to the set of applications that has its basis on the principles of nanoscience. Nanoscience is the field of science that focuses on the study of materials at the atomic levels in the range from 1 to 100 nm (Mehta, 2002). The pioneering idea of developing things by the individual arrangement of atoms was proposed by Nobel Laureate physicist Richard Feynman in 1959 (Dutta, Lawson & Marcinko, 2006). According to Prasad (2008), the size of the nanometre can be measured by relating it to a typical width of a human hair that is approximately 50,000–100,000 nanometres wide (p.225).

Moreover, nanotechnology was only discovered as a research field in the mid-1990s, but in a short time has become a significant research activity for scientists in a more extensive scientific field. Managers and practitioners alike have claimed that nanotechnology will lead to a global industrial revolution (Iavicoli et al., 2014) and the National Nanotechnology Initiative (NNI) predicted that most of the semiconductors and the pharmaceutical industry will soon be dependent on nanotechnology.

Nanotechnology refers to the creation or use of functioning structures that are developed from atomic or molecular scales with (at least) a single, characteristic dimension gauged in the form of nanometres. Functional structures' size gives them novel, enhanced, physical, chemical and biological properties, phenomenas and processes. In this regard, objects frequently indicate physical attributes that are distinct from atoms or bulky matter when their structural features are intermediate between isolated atoms and bulky materials, ranging from 1–100 nanometres (Prasad 2008,225).

At the nanometre scale, a phenomenon is likely to be in a different environment, whereas the properties of the matter measured in it may not be as predictable as those noted in larger sizes. Significant behavioural changes are brought about by the ongoing transformation of characteristics in relation to the miniscule size, as well as the occurrence of whole novel phenomena, such as quantum confinement. According to Prasad (2008), the development and

monitored replication and integration of nano-materials and nano-devices is expected to bring about a scientific and technological revolution.

In the circles of researchers and practitioners, it is expected that nanotechnology will present several economically pertinent applications in different industries in the near future, applications that cover the chemical industries, materials and manufacturing, engineering and construction, nano-electronics and computer technology, pharmaceutical and medical industries, aeronautics and space exploration, agriculture and water environments, and energy, global trade and even competitiveness. Suffice to say that studies dedicated to nanotechnology offer a veritable array of innovation, and advantages to the whole of society (Aydogan-Duda, 2012). On the basis of the report drawn up by the UN's International Centre for Science and High Technology 2005, brought up at the meeting known as the North-South dialogue of nanotechnology, nanotechnology is among the newly-occurring research fields that are predicted to positively affect developing as well as developed nations. For instance, nanotechnology is known to be used to purify water in poor countries and it is also equally known to be used to manufacture superior computer chips in developed countries. Hence, in this regard, countries are rushing to invest in research and development (R&D) when it comes to nanotechnology.

More importantly, it is crucial for future economic progress and for strengthening global markets that nanotechnology is developed via technology entrepreneurship. In the context of Jordan, a developing country, evidence indicates several obstacles that prevent the creative work activities in the nano domain and therefore, the question arises as to how to go about resolving the faced obstacles and barriers in the field of nanotechnology.

Diffusion of Innovation Theory

Diffusion refers to a process characterising the adoption of innovation by community members. The theory highlights four factors that affect innovation adoption. These factors are: the innovation, communication channels, time, and lastly, the nature of the society in which the innovation is launched. In relation to this, Ryan and Gross's (1943) work concerning rural sociology is often cited as the initial step in diffusion research.

According to Rogers (1995), four main theories are attributed to dealing with the innovation diffusion, which include innovation-diffusion process theory, individual innovativeness theory, the rate of adoption theory and the theory of perceived attributes. Rogers (1995) added that the innovation-process is described as an information-seeking and processing activity, within which the individual is encouraged to minimise uncertainty regarding the innovation in terms of its advantages and disadvantages (p.172). The theory has its basis on time and five different stages, with the first stage being knowledge. In other words, target

adopters should first learn about the innovation. The second stage is the persuading of the adopters of the innovation's merits and the third is the decision of the adopters to adopt the innovation. The fourth stage following the innovation adoption, is its implementation, and finally, the fifth stage is the confirmation of that the adoption decision was the right decision to make. The achievement of these stages leads to diffusion.

Moving on to the individual innovativeness theory, this theory has its basis on who adopts the innovation and when it is adopted. The percentage of individuals that adopt innovation is often indicated by a bell-shaped curve, where the first adopter category is known as innovators (2.5%). This category of adopters is also known as risk-takers and leaders. The second category is labelled as early adopters (13.5%), they often adopt the innovation early and disseminate the innovation through word of mouth. The third and fourth categories are labelled as early majority and late majority, with each constituting 34 percent of the potential adopters in the population. The early majority is often convinced to adopt the innovation by the innovators and the early adopters, while the late majority waits until they are convinced of the advantages of the adoption. The final category is the laggards, constituting 16 percent and they are those who are not as eager to adopt innovation until it is necessary for them to do so – in most cases, they never become adopters.

With regards to the theory of rate of adoption, it posits that innovation adoption is optimally indicated by the s-curve on the graph. The theory proposes that innovation adoption increases slowly but gradually at the onset, followed by rapid growth, after which it tapers off, becomes stable, and finally declines. On the other hand, the theory of perceived attributes has its basis in the notion that individuals adopt innovation if they are convinced that it has several attributes, including; relative advantage, compatibility with the existing values and practices, simplicity over complexity, trialability and lastly, observable results.

Nanotechnology as Technological Innovation

According to Rogers (1995), diffusion is the process by which an innovation is relayed via specific channels through time among the societal members (p.35). He explains that innovation refers to a novel idea, practice or object that is new to the individual, and he limited his discussion to technological innovations. He claims that a technology is created for some instrumental activity that minimises the uncertainty in the relationships characterised as cause-and-effects entailing the achievement of a goal (p.35). On the basis of his definitions, nanotechnology may be described as technological innovation as it is known to be a novel idea among a population of potential adopters.

Based on this background, it is invaluable to apply the principles of the diffusion theory to provide an insight into nanotechnology diffusion in the social system according to several reasons.

First, the theory serves as a framework that assists the advocates of nanotechnology to know the reason behind its adoption by several individuals and its rejection by others. Supporters of the theory can make use of the diffusion theory to shed light, predict and explain factors that precipitate the innovation diffusion. The diffusion theory assists the nanotechnology field to determine qualities like relative advantage and compatibility, among others, that could propel its attractiveness to potential adopters. The theory can serve as a framework to examine communication channels employed to disseminate nanotechnology information, the time taken for its dissemination, and the type of society that adopters hail from.

Second, nanotechnology is a constantly changing field with hardware and software components introduced and thus, it is crucial to have an accurate understanding of its introduction to the social system. For this, the diffusion theory assists in such understanding.

Third, diffusion research is full of several successfully validated models that can be utilised to create a successful diffusion advocacy initiative for nanotechnology. As previously mentioned, there are four factors that influence innovation adoption. These factors are: innovation, communication channels used to disseminate innovation information, time, and the societal nature to which it is introduced in (Rogers, 1995).

Furthermore, the diffusion of innovation theory has been examined extensively from different perspectives across many levels (individual, organisation and societal). Studies of such calibre have tried to gather information concerning adoption patterns (Abrahamson, 1991). Some have tried to gather information concerning the characteristics of early and late adopters in organisation (Rogers, 1995), while others concentrate on the characteristics that distinguish the innovators, on the basis of costing system, from the non-adopters (Mohr, 1982). Aydogan-Duda (2012) examined the relationship between diffusion of nanotechnology and the external environment, while Clarke (1999) focused on the barriers of adoption and implementations. Some other studies have looked into the adoption and implementation processes but what makes the present study unique is its examination of the accounting barriers and problems of nanotechnology implementation in the context of Jordan, a developing country. This examination is conducted to confirm the relationship between innovation creation and implementation.

Accounting Barriers and Problems: Empirical Literature

Several researchers and practitioners have conducted empirical studies on the topic of nanotechnology. More specifically, Darby and Zucker (2003) and Bowers and Cernac (2008) predicted that nanotechnology will ultimately result in rapid improvement, in the case of the process of production. In turn, this will decrease the unit of product cost via effective inputs utilisation. In a similar study, West (2008) predicted that several products types will be produced fast like a printer and computer that are capable of generating multiple data file copies at minimal cost. West (2008) also claimed that nanotechnology will minimise the cost of products through files copying as nano-products can be created through ways that are cost-effective, using electricity at a higher rate than was ever possible (Centre for Responsible Nanotechnology, n.d.).

Nano-applications provide several advantages, which include the reduction of costs of production and storage, a reduction of pressure on raw materials, improving the quality of products, cleaning-up technologies and encouraging sustainably manufactured products. In contrast to such advantages, financing and accounting faces several risks: health and safety risks, social issues and market uncertainty. This study aims to present such accounting and financing risks.

According to Aydogan-Duda (2012), there are some issues that prevent the diffusion of nanotechnology in the U.S. that relate to organisational activities like R&D, investment, intellectual property (IP), economic development and commercialisation, workforce development and education, occupational health, public policy and health, and government budget, to name a few. Providing an overview of these barriers can indicate the top barriers to the implementation of nanotechnology in the USA that are related to both accounting and financing. For instance, in R&D, the issue of high cost may be faced by small companies that are unable to afford the cost of nanotechnology instrumentation, equipment and facilities. This is due to the investment issue and the required investment capital at the onset of business ventures for the employment of the required educated staff, advanced R&D systems, high processing of nanoproducts, long-lead time, and the lack of process scalability.

Moreover, in a study conducted by Ahmadi, Rezaei and Kheiri (2013), the authors carried out a survey in Iran to determine the importance of nanotechnology development in the framework of the National Innovation System, and the barriers that prevent its diffusion in the sector of agriculture. They distributed 120 questionnaires to experts employed by 15 national institutions and agricultural research centres in the country. Their analysis findings show that financial support was the top explanatory variable, followed by communication-management, cognitive-learning and operating infrastructure. The above discussed studies indicate the importance of accounting and financial factors on the nanotechnology diffusion

and implementation. Added to the above issues, there is a high risk for the use of nanotechnology in terms of the significant costs invested for the establishment of its factories. Factories who intend to establish nano-manufacturing methods will have to invest more resources at the onset more than the investment they will have if they opt into the traditional manufacturing method. This is because the development of assemblers and replicators require costs and the same scenario applies for the initial production process, sales and after sales (Dutta et al., 2006). Consequently, investors will face issues in providing cash outlay for the capital, and creditors will have to provide considerable capital while facing the uncertainty of their investments owing to the novelty of nanotechnology. This is compounded by the risks in the sales volume uncertainty that challenges the forecasting of future, free cash flows, despite the fact that traditional manufacturing costs are greater compared to the nano-manufacturing costs, as explained by Dutta et al. (2006). They explain that the high investments in establishing nano-factories at the onset will lead to increased effects of errors in forecasting. In comparison to nano-manufacturing, traditional manufacturing costs incurred are paid step-wise during the process of production, sales and after sales, and thus, risks are less compared to nano-manufacturing, as risks are distributed throughout the process.

Furthermore, studies in literature dedicated to the nanotechnology topic including Cooper (1988), Innes and Mitchell (1995) and Kruemwield (1998), relate that the advanced technologies' implementation in the process of production has led to higher automation and extensive cost structure changes. The cost structure changes involved direct labour costs being replaced by indirect costs. This shift has led to an increased overhead cost that requires accurate allocation of product costs. In this regard, the determination of accurate cost is crucial in order to realise a competitive edge in the market as successful companies refer to those that are capable of achieving optimum quality, less costs and lower price.

In addition to the above, researchers supported the importance of cost allocation in valuation and the assessment of inventory for the purpose of external reporting, planning and monitoring the company activities, and for other strategic decisions (e.g., Andersen, 1995; Horngren, Datar & Foster, 2003; Cooper & Kaplan, 1988b; Drury, 2004). Some instances of strategic decisions are: decisions pertaining to the production or purchasing of material/services for various products/services, those pertaining to price products and services geared towards increasing the competitiveness of the firm, those pertaining to the addition and removal of different products/services, and those pertaining to the expansion and contraction of a company's segment.

Lastly, an equally important issue in the use of nanotechnology is related to job opportunities, as nanotechnology factories use machines and technologies in lieu of workers in their production and sales – this will heighten the unemployment of workers and those that are currently employed will resist the shift towards nanotechnology and its adoption (Sharify et

al., 2010). On the other hand, new technology may create new job opportunities to overcome employment issues. This is where the need arises for further studies in the future concerning the potential issues and risks of using and implementing nanotechnology. This is particularly significant as prior studies (e.g., Maynard, 2004; Hoyt & Mason, 2007) claim that nanotechnology may lead to workers and consumers' health problems in the future and this may affect the accounting community and the insurance sector.

Research Design and Methodology

A mixed methodology was used in the current study, including both quantitative and qualitative methods. The researcher used the following series of steps to employ the mixed method. First, the questionnaire survey was used as a quantitative method to understand accounting barriers and issues hindering the implementation of nanotechnology among Jordanian companies. The population this survey was distributed to consisted entirely of researchers and experts at the Nanotechnology Institute at JUST. Second, face-to-face, semi-structured interviews were conducted as a qualitative method to support and interpret the findings from the questionnaire survey, as well as to add further information about accounting barriers and problems inherent in the implementation of nanotechnology.

Research Results

Quantitative Data Analysis

Information of Respondents

This subsection presents information regarding individual respondents to the questionnaire surveys. This information includes work position, academic qualifications, field experience and experience in the respondents' current positions at JUST.

Work Position. Table 4.1 reveals that 12.5 percent (2) of those completing the questionnaire were deans or dean's assistants, 31.25 percent (5) were department heads, 18.75 percent (3) were experts, and 37.5 percent (6) were researchers.

Table 4.1: Work position in the Nanotechnology Institute at JUST

	Frequency	Percent	Valid Percent	Cumulative Percent
Dean or Dean's Assistant	2	12.5	12.5	12.5
Head of Department	5	31.25	31.25	43.75
Expertise	3	18.75	18.75	62.5
Researcher	6	37.5	37.5	100.0
Total	16	100.0	100.0	

Academic Qualifications. Respondents were asked to state their academic qualifications. Table 4.2 shows that the majority of respondents, 56.25 percent (9), were doctoral degree holders, 18.75 percent (3) had a master's degree, and 25 percent (4) had a bachelor's degree. In other words, all of the respondents had higher education qualifications.

Table 4.2: Academic Qualification in the Nanotechnology Institute at JUST

	Frequency	Percent	Valid Percent	Cumulative Percent
PhD degree	9	56.25	56.25	56.25
Master degree	3	18.75	18.75	75
Bachelor degree	4	25.00	25.00	100.0
Total	16	100.0	100.0	

Field Experience. Respondents were asked to indicate the length of their work experience. Table 4.3 reveals that 62.5 percent (10) of respondents had worked less than three years, 31.25 percent (5) of respondents had worked between two and five years, and 6.25 percent (1) had six to ten years of experience.

Table 4.3: Total experience in this field of study

	Frequency	Percent	Valid Percent	Cumulative Percent
Less than 2 years	10	62.5	62.5	62.5
2 – 5 years	5	31.25	31.25	93.75
6 – 10 years	1	6.25	6.25	100.0
Total	16	100.0	100.0	

Experience in the Nanotechnology Institute at JUST. Respondents were asked to indicate the length of their current work experience at JUST. Table 4.5 shows that 62.5 percent (10) of respondents had worked less than two years in their current institution, while 37 percent (6) had worked between two and five years. Table 4.5 shows all respondents' total work experience at the Nanotechnology Institute at JUST.

Table 4.4: Total experience in this field of study

	Frequency	Percent	Valid Percent	Cumulative Percent
Less than 2 years	10	62.5	62.5	62.5
2 – 5 years	6	37. 5	37. 5	100.0
Total	16	100.0	100.0	

Barriers and Problems of Nanotechnology Implementation

Sixteen individual respondents who had experience and knowledge regarding the subject of nanotechnology were requested to explain their decisions about the problems of nanotechnology implementation. The respondents were asked to answer a list of 16 potential accounting problems that may explain why Jordanian companies have not implemented nanotechnology. The individual respondents were asked to rate these items on a five-point scale in which 1 = strongly disagree and 5 = strongly agree. The possible reasons for the respondents' answers were explored by examining the mean scores of each item. These responses are summarised in Table 4.5.

Table 4.5: Barriers and problems of nanotechnology implementation

	N	Min	Max	Mean	Std.
The necessary and substantial investment capital, cash, is lacking early in business ventures for highly educated personnel and advanced R&D systems; high processing costs for nano-products	16	2	5	4.00	.894
Incomplete intellectual system and laws, and poor insurance of its implementation in nanotechnology	16	2	5	3.94	1.063
Lack of adequate funding in the field of nanotechnology	16	2	5	3.94	1.063
Inadequate budget allocation among units and sections in Jordanian companies.	16	2	5	3.75	.775
Lack of tax incentives by the government to encourage safer business environment	16	2	5	3.56	1.031
Consultants too costly	16	2	4	3.50	.894
Costly to switch to nanotechnology	16	2	5	3.50	.966
Nanotechnology distorts the cost structure by increasing the rate of indirect cost which needs more accurate allocation to the unit of product.	16	2	5	3.38	1.025
Lack of competition rate which face Jordanian companies	16	2	5	3.31	1.138
Lack of government assistance to help finance nanotechnology infrastructure that requires higher investments and costs for multidisciplinary ventures, and risk research of the environment and human health.	16	2	4	3.25	1.000

The perceived benefits of nanotechnology do not justify the cost of implementing it.	16	2	4	3.19	.911
This technology may cause health problems for workers and consumers in the future, this will have an impact especially on the accounting community.	16	1	4	2.81	1.047
Nanotechnology may cause health problems for workers and consumers in the future, which will create problems for the insurance sector.	16	1	4	2.69	1.014
Perception of long lead time for nano-products, and lack of process scalability.	16	1	4	2.69	1.078
Lack of knowledge and awareness of how to get financial support to implement nanotechnology	16	1	4	2.69	1.014
Expecting resistant from employees	16	1	4	2.13	.957

Table 4.5 reveals that the most important financial and accounting barrier to the implementation of nanotechnology is the following issue: "The necessary and substantial investment capital, cash, is lacking early in business ventures for highly educated personnel and advanced R&D systems" (mean score = 4.00). This was followed by incomplete intellectual system and laws, poor insurance of nanotechnology implementation, and the lack of adequate funding in the field of nanotechnology (mean score = 3.94). These issues were followed up by inadequate budget allocation among units and sections within Jordanian companies (mean score = 3.75) and a lack of tax incentives by the government that encourage safer business environments (mean score = 3.56). This was consistent with previous studies, such as Aydogan-Duda (2012), which concluded that inherent difficulties, such as the lack of organisational activities, including R&D, investment, economic development and government budgets, are major barriers to nanotechnology implementation. Similar proof is reported by Dutta et al. (2006), who state that capital plays an important role in nanotechnology implementation because investors will face issues in providing cash outlay for the capital and creditors will have to provide considerable capital while facing the uncertainty of their investments (due to the novelty of nanotechnology). In their study in Iran, Ahmadi et al. (2013) found that financial support is a major barrier to nanotechnology implementation.

The items stating that consultants are too costly and that it is costly to switch to nanotechnology (mean scores = 3.50) were mentioned as inherent difficulties; this is consistent with previous researchers' findings, such as Dutta et al. (2006). The item, 'nanotechnology distorts the cost structure by increasing the rate of indirect cost which needs

more accurate allocation to the unit of product' (mean score = 3.38) was also cited as a major barrier to the implementation of nanotechnology in Jordanian companies. This was followed by the lack of a competitive rate facing Jordanian companies (mean score = 3.31). Similar proof is reported by Rababah (2017), who states that the use of nanotechnology in production processes will lead to changes in the cost structure, distorting the cost of the product. The reasons for the lack of implementation of nanotechnology within Jordanian companies are similar to those documented in other countries.

From Table 4.5, it can be perceived that there is a strong disagreement with the statements, "Expecting resistance from employees," (mean scores = 2.13) and, "Lack of knowledge and awareness," (mean score = 2.69) as barriers to implementing nanotechnology. This result contrasts with the results of Rababah (2017), who said that a lack of knowledge and awareness is an important barrier to the implementation of nanotechnology in companies.

Qualitative Data Analysis

Data Analysis for Non-Adopter Companies

In this section of the study I will analyse the qualitative data collected from the interviews conducted with deans, dean's assistants, researchers and experts at the Nanotechnology Institute at JUST. The aim of the data analysis of these interviews is to support and confirm the questionnaire results. This is because the descriptive analysis is not enough to interpret the results, as the number of questionnaire respondents was low and it was difficult to conduct a more meaningful data analysis. For this data analysis I will use within data and cross data analyses.

Within Data Analysis of the Respondents. Within data analysis provides information about each respondent and his or her experiences with nanotechnology. I interacted with each respondent to collect more information about the accounting barriers and problems of nanotechnology implementation within Jordanian companies. Following the collection of information from each respondent, I summarised the data from all respondents within a cross data analysis, as is explained in the next section.

Cross Data Analysis of the Respondents. This section provides an outline of a cross data analysis. It includes all of the barriers and problems identified by the respondents and their assessments in order to arrive at an overall assessment of the most important accounting barriers and problems that hinder nanotechnology implementation within Jordanian companies. The analysis of the six respondents has been summarised in Table 5.1. Qualitative analyses, along with quantitative ratings, were accomplished to generate this summary.

Table 5.1: Summary of Cross Data Analysis

Factors:							
	Respondents:	***1***	***2***	***3***	***4***	***5***	***6***
Reasons for non-implementation of nanotechnology:							
Costly to switch to nanotechnology.		√	**X**	√	**X**	**X**	√
Lack of knowledge and awareness of how to get financial support to implement nanotechnology		**X**	√	√	√	√	**X**
Nanotechnology distorts the cost structure by increasing the rate of indirect cost which needs more accurate allocation to the unit of product.		√	√	**X**	**X**	**X**	√
The necessary and substantial investment capital, cash, is lacking early in business ventures for highly educated personnel and advanced R&D systems.		√	√	**X**	√	√	**X**
Incomplete intellectual system and laws, and poor insurance of its implementation in nanotechnology.		**X**	**X**	**X**	√	**X**	**X**
Lack of adequate funding in the field of nanotechnology.		√	√	√	√	√	**X**
Consultants are too costly.		√	√	**X**	√	**X**	√
Nanotechnology may cause health problems for workers and consumers in the future, which will create problems for the insurance sector.		**X**	**X**	√	**X**	**X**	√
Low economic growth in Jordan caused by the wars in bordering Arab countries (specifically Syria and Iraq), add to that the financial shortfall in Jordanian universities budgets and then the shortage in the support of nano-projects.		**X**	√	**X**	**X**	√	**X**

Legend:√□= the factors supported by the interviewee, **X**□= the factors that are not supported by the interviewee.

The six respondents interviewed said that Jordanian companies do not implement nanotechnology because there are barriers to this implementation; some of these barriers and problems are related to financing and accounting. The most important reason was "the lack of

adequate funding in the field of nanotechnology." The cross data analysis shows that five out of six respondents think that a "lack of adequate funding in the field of nanotechnology" is a major barrier to nanotechnology implementation. Four out of six respondents said that the fact that "the necessary and substantial investment capital, cash, is lacking early in business ventures for highly educated personnel and advanced R&D systems" is an important reason for the lack of nanotechnology implementation. Also, four out of six respondents said that consultants are too costly and that the lack of knowledge and awareness of how to get financial support to implement nanotechnology is a barrier to its implementation.

These results are followed up by three out of six respondents who said that the following items, "distorts the cost of products by increasing rate of indirect cost which need accurate allocation to the unit of product," and, "costly to switch to nanotechnology," are both barriers to the implementation of nanotechnology. The last two barriers, which are, "nanotechnology may cause health problems for workers and consumers in the future, which will create problems for insurance sector" and, "incomplete intellectual system and laws, and poor insurance of its implementation in nanotechnology," were mentioned by two and one respondents, respectively.

In addition, these interviews generated other potential accounting reasons for the lack of the implementation of nanotechnology within Jordanian companies. Interviewees mentioned that low economic growth in Jordan, caused by the wars in bordering, Arab countries (specifically Syria and Iraq), is a factor. Interviewees also mentioned that and the Jordanian universities' budget deficit are also a barrier to nanotechnology implementation.

Conclusion

The current study's mixed methodology, involving both quantitative and qualitative measures, was used to reveal the accounting-related barriers and problems which are facing the implementation of nanotechnology in Jordanian companies. The questionnaire survey was followed by interviews with employees, researchers and experts at the Nanotechnology Institute at JUST to support the questionnaire's results and to discover new variables.

The analysis of the quantitative research results reveal that financial and accounting factors play a role in preventing the diffusion of nanotechnology, including items such as, "the necessary and substantial investment capital, incomplete intellectual system and laws, and poor insurance", "lack of adequate funding in the field of nanotechnology," and inadequate budget allocation among units and sections. In the same way, the analysis of the qualitative research also found that financing and accounting problems play a role in the diffusion of nanotechnology; the greatest reason for the non-implementation of nanotechnology was "the lack of adequate funding in the field of nanotechnology," followed by, "the necessary and

substantial investment capital, cash, is lacking early in business ventures for highly educated personnel and advanced R&D." The respondents said that consultants are too costly and that the lack of knowledge and awareness of how to get financial support to implement nanotechnology is a barrier for implementing nanotechnology. The interviews' analysis depicts that there may be additional variables that influence the diffusion of nanotechnology in Jordan, such as low economic growth and the Jordanian universities' budget deficit.

All of the previously mentioned problems could be hindering the implementation of nanotechnology. However, these accounting problems may be originating from the external environment before and during the implementation, or they may result from the implementation process itself and the use of nanotechnology to produce nano-products. For example, a lack of investment capital and funding is an accounting problem that may hinder companies before and during the implementation, whereas the distortion of cost structures results from the implementation of nanotechnology, therefore, indirectly influencing the diffusion.

The present research explores for the first time the accounting problems influencing the diffusion of nanotechnology implementation. This study is significant due to its contribution to the existing research on nanotechnology in developing countries, since the majority of previous studies focused only on the implementation of nanotechnology in western, developed countries, such as the United States and the United Kingdom. This research contributes to the general understanding of the implementation of nanotechnology, particularly in eastern, developing countries, such as Jordan. Furthermore, this study encourages the exploration of further research regarding inherent accounting problems in nanotechnology and enhanced collaboration between accountants, interested institutes, universities and companies to increase the effectiveness of the implementation process. This study will lay the foundation for future researchers to grasp the most significant accounting-related problems, which are facing the implementation of nanotechnology in developing countries, as well as how we can overcome these problems and increase the implementation rate of nanotechnology.

Jordanian companies must have a clear vision of the importance of nanotech research and development and how nanotechnology will alter the future of industry. Jordanian companies will benefit economically by increasing their use of nanotechnology research and development because the implementation of nanotechnology will lead to the achievement of higher quality products, benefiting consumers and achieving competitive advantages, all while creating new, high-tech jobs.

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